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TRANSLITERATION

There is no ideal system of transliterating Russian; each has its advantages and disadvantages. For the translation of *Geokhimiya* we have chosen the system used by *Chemical Abstracts*, partly because of its wide acceptance by other journals and partly because of certain advantages in alphabetization of names. The principal differences between this system and others in common use are as follows:

Russian	Chem. Abs.	Others
Х	kh	h
Ц	ts	tz
Щ	shch	sch
Ю	yu	iu
Я	ya	ia

THE RATE OF SILT DEPOSITION IN THE INDIAN OCEAN

V. I. Baranov and L. A. Kuzmina

V. I. Vernadskii Institute of Geochemistry and Analytical
Chemistry, Academy of Sciences, USSR, Moscow

Abstract

The ionium, thorium and uranium contents of five selected cores from the lian Ocean have been determined. Parallel iron and manganese determina-ns for the same horizons permit fixing a definite dependence of uranium and rium contents on iron and manganese concentrations. The thorium content nges in the upper horizons from about 0.4 to 3.0 micrograms per gram, which rees with the increased calcium content (up to 40 to 48%); in the intermediate ers the Th-concentration reaches 7 to 10 micrograms per gram. The uranium ncentrations are 0.1 to 0.3 micrograms per gram; the ionium concentration x 10^{-10} grams per gram of silt, which is 30 times its equilibrium values with anium; the deposition rates, calculated according to ionium, give values of the der of 1600 to 2000 years.

The first integrated Soviet Antarctic Expedition of 1956 investigated arge area off the shore of the Antarctica, the Tasman Sea, and the ntral part of the Indian Ocean. This Soviet expedition was the first e to examine systematically the East Antarctica and the southern rt of the Indian Ocean. A study of the sea-bottom sediments was one the main investigations. A large number of sediment samples was en for this purpose, by means of the "Okean-150" scoop of the aight-flow and the piston sampling tubes. Some of these were kindly ced at our disposal by the geologist, A. P. Lisitzyn, for a study of sedimentation rates of marine silts by the ionium method.

This article is a preliminary report on five sedimentary sections m the southeastern part of the Indian Ocean. According to A. V. ivago and A. P. Lisitzyn [1], all of this region is characterized by yey-diatomaceous and diatomaceous silts, succeeded in the north by tomaceous-foraminiferous and by entirely foraminiferous sediments. ys and clayey-diatomaceous silts are distributed extensively in the ipheral parts of the oceanic bed which adjoins the continental shelf.

The first, and probably the only estimations of sedimentation rates the Indian Ocean were made by W. Schott in 1939 [2]. He assumed t the latest glaciation took place 20,000 years ago, and used the ght of the surface layer of foraminiferous and diatomaceous silts a measure of the thickness of sediment deposited since that time. calculations showed that globigerina and the diatom silts were umulating at nearly the same rate of 0.59 and 0.54 cm per 1000 years respectively (uncorrected for moisture and disturbance of the section by sampling).

Despite the common use of the ionium method of determining the sedimentation rates of marine silts, the method has not been used to determine sedimentation rates in the Indian Ocean. Even so, its application to oceanic sediments is still a subject of some interest. Our work was undertaken for that reason, as a part of the general problem dealing with certain relationships in the behavior of the radioactive elements in marine silts. As previously stated, three of the stations we had examined, Nos. 107, 103, and 17, are on the periphery of the southern part of the Indian Ocean (which is characterized by its clayey-diatomaceous and diatomaceous silts). The sections at stations 97 and 127 were taken farther north, in the region of foraminiferous and clayey-limy silts.

Sedimentation rates were determined from the changes in the concentration of ionium with depth.

Thorium and uranium were also determined and the results were compared with the analytical data for iron and manganese. The radioactive elements, ionium and thorium, were determined in the same aliquots, by the method we had developed. Uranium was determined by the luminescent fluoride bead method [L. I. Leonova, 3]. We will now discuss the results for each of the sedimentary sections.

Station 97 (40° 32′ S; 120° 35′ E)

The chocolate-brown foraminiferous silts at this station are very homogeneous.

The amounts of thorium, ionium, uranium, iron, and manganese in the vertical section are reported in Table 1.

The results indicate a high degree of variability in the chemical composition of the silts. Moreover, the upper horizon is impoverished significantly both with respect to iron and to manganese in comparison with the deeper horizons in the section. This is entirely in harmony with the amounts of uranium and thorium, the radioactive elements

Table 1. Content of U, Th, Io, Fe_2O_3, MnO in Section at Station 97

Depth of Horizon, cm	Th	U	Io*	Fe_2O_3 %	MnO %	(Io-U): Th	(Io-U): MnO	(Io-U): Fe_2O_3
	micrograms/gram							
6-20	1.7	0.10	11.0	1.75	0.10	6.4	109	6.2
42-50	4.4	0.30	14.0	3.35	0.32	3.1	43	4.1
92-97	9.5	0.66	5.0	9.42	0.92	0.45	4.7	0.46
147-152	10.0	0.78	1.1	9.26	0.96	0.022	0.33	0.03
180-185	7.3	0.46	2.0	8.94	0.60	0.21	2.6	0.17

*In uranium units

resent in micro- ɔncentrations: ıeir amounts in ıe upper hori- ɔns are only ɔout one-fifth those in the ɔwer. We may ɘe, therefore, this particular ɘction, that the ɘhavior of the ıdioactive ele- ents is deter- ined apparent- by the macro- ɔnstituents. he graphical ɘpresentation of ır results for h, MnO and e_2O_3 in Figure illustrates the oportional de- ɘndence of orium on iron ıd manganese, ith some insignificant departures in either direction.

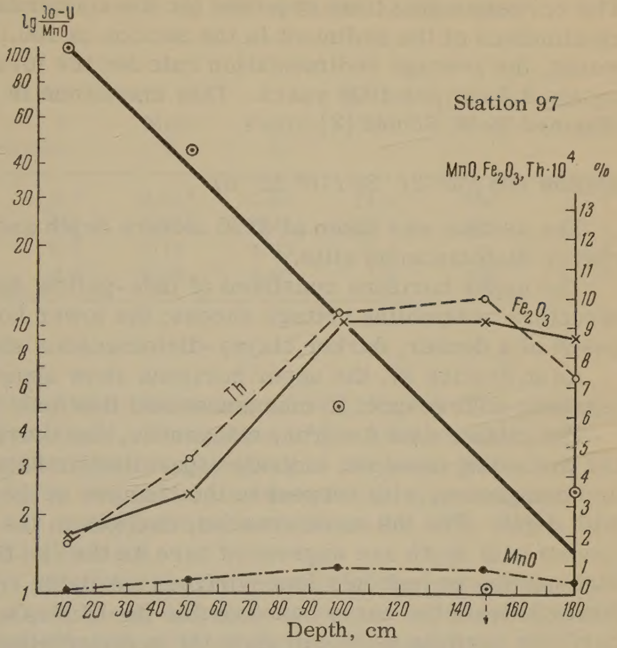

Fig. 1. Ionium, thorium, iron, and manganese in silts of section 97.

Consequently, the concentration of ionium, a thorium isotope, must so be proportional to the amounts of the sesquioxides, provided, of ɔurse, that the manner of the accession of both isotopes to the ɔttom of the sea is the same.

Plotting of the (Io-U):MnO, and the (Io-U):Fe_2O_3 ratios on the semi- garithmic scale confirms our supposition. The magnitudes of the :Th ratio also run parallel to these curves, showing that ionium and orium behave identically. It is evident therefore that the Io:Th ratio just as indicative of the sedimentation rates as the Io:MnO and the :Fe_2O_3 ratios. Moreover, this ratio indicates that there is no selec- ve migration of either one of the isotopes in the silt. As we see in gure 1, the point representing the 150 cm depth is off the curves. ıis fact cannot be explained because our section is insufficiently ep.*

The sedimentation rate for the silts in this section, as calculated ɔm the (Io-U):MnO ratio, Figure 1, proves to be 1 cm per 2000 years.

ɔt only the 150 cm but also the 100 and the 180 cm points are off the curve in igure 1. That is 3 out of 5 points are off the curve. VPS

The corresponding time required for the accumulation of the upper 50 centimeters of the sediment in the section is 100,000 years. In other words, the average sedimentation rate for the foraminiferous silt equals 0.5 cm per 1000 years. This magnitude is close to the results obtained by W. Schott [2].

Station 103 (50° 21 ' S; 110° 12 ' E)

The section was taken at 3850 meters depth and was composed of clayey-diatomaceous silts.

The upper horizons consisted of pale-yellow diatomaceous silt of a structure resembling cottage cheese; the lower horizons were composed of a denser, darker clayey-diatomaceous silt.

As in Section 97, the upper horizons show about a 10-fold impoverishment, with respect to manganese and thorium.

The plotted data for iron, manganese, and thorium (Figure 2), as in the preceding example, indicate a parallelism between thorium, iron and manganese, with respect to the changes in their concentrations with depth. For the same reasons, changes in the concentration of ionium with depth are expressed here as the (Io-U):Fe_2O_3 ratio. Unfortunately, we had only four horizons available from this section. Nevertheless, the curve based on the (Io-U):Fe_2O_3 ratio for these horizons permits us to calculate the sedimentation rate for the silt. This rate proves to be 1 cm per 1600 years.

Table 2 also shows that the 145 cm horizon is somewhat higher in uranium than the overlying horizon, despite the somewhat lower concentrations of MnO and Fe_2O_3.

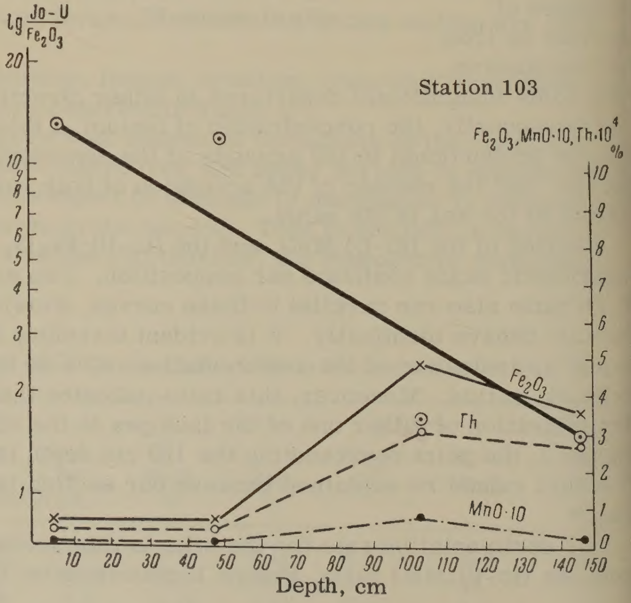

Fig. 2. Ionium, thorium, iron, and manganese in silts of section 103.

Station 107 (50° 48 ' S; 90° 54 ' E)

This station is situated in the region of clayey-diatomaceous and diatomaceous silts. Its upper

Table 2. Content of U, Th, Io, Fe_2O_3, MnO in Section at Station 103

epth of rizon, cm	Th micrograms/gram	Io*	U	MnO %	Fe_2O_3 %	(Io-U): Th	(Io-U): MnO	(Io-U): Fe_2O_3
-11	0.4	6.0	0.4	0.017	0.48	14.0	330	11.7
50	0.4	5.6	0.1	0.017	0.48	13.7	323	11.6
105	3.4	8.6	0.5	0.10	4.95	2.4	81	1.6
145	3.0	7.6	2.2	0.05	3.67	1.8	108	1.5

uranium units

orizons are represented by a diatomaceous silt; its lower horizons, y a clayey-diatomaceous silt. The colors of the silts change gradu- ly from pale pink in the upper to pale gray in the lower horizons. his change appears to be due to the increase in the clay fraction.

The chemical and the radiochemical results on the silts of this ection are presented in Table 3.

The data in Table 3 show that the Th-content of the uppermost and wermost horizons are only one-third of the values in the intermedi- e horizons. Such deficiencies of thorium may be explained, it pears, by the nearly proportional deficiencies of iron and especially manganese in the same horizons.

The content of uranium is also almost proportional to the content of on and manganese: uranium fluctuates between 0.5 and 1 micrograms r gram of silt. These results, in their diagrammatic representation, press a very intricate pattern in the chemical and radiochemical mposition of the silts. The greatest fluctuations are observed be- nning with the 150 cm horizon, to such a degree that it is not possible calculate the sedimentation rates for silts below this level. By eatments of the curve representing the upper horizons, we obtain the dimentation rate equal to 1 cm per 1100 years.

Table 3. Content of Th, U, Io, MnO, Fe_2O_3 in Section at Station 107

Depth of orizon, cm	Th micrograms/gram	Io*	U	MnO %	Fe_2O_3 %	(Io-U): Th	(Io-U): MnO	(Io-U): Fe_2O_3
5-20	2.8	10.0	0.62	0.051	1.91	3.3	184	5.0
3-70	7.0	10.0	1.0	0.114	3.59	1.3	80	2.5
0-129	9.8	7.0	1.0	0.168	5.20	0.61	35	1.1
4-176	8.0	10.2	0.5	0.055	4.31	1.2	180	2.2
0-200	10.6	9.6	0.3	0.067	5.18	0.9	140	1.8
4-266	3.2	6.0	0.7	0.049	4.63	1.6	108	1.1

uranium units

Station 17 (60° 25 ' S; 90° 48 ' E)

As shown by the coordinates this station is practically on the periphery of the oceanic bed, on the border of the continental slope of Antarctica, and at the boundary between the clayey-diatomaceous silts and iceberg sediments. The sediments at this station are clayey-diatomaceous silts, pale gray throughout the section.

Since the length of this section is barely over 1 meter, and since only three horizons were analyzed, the sedimentation rates can be stated only in a most general form (Table 4).

One may note that the upper horizon of this section is very slightly higher in thorium than the lower horizon. Uranium is 2 to 3 times higher than at stations 97, 103 and 107 and is about 1.7 micrograms per gram. The sedimentation rate of the silt is about 1 cm per 800 years, as indicated by the (Io-U) : MnO ratio. It is clear that the three points are insufficient for any reliable estimation of the sedimation rate.

Table 4. Content of Th, U, Io, MnO, Fe_2O_3** in Section at Station 17

Depth of Horizon, cm	Th	Io*	U	MnO %	(Io-U): MnO
	micrograms/gram				
5-10	12	6.0	1.6	0.08	55
93-88	8	4.5	1.4	0.09	33
107-112	9	2.9	2.0	0.09	10

*In uranium units

**Not reported in the original

Station 127 (30° 41 ' S; 60° 42 ' E)

This site is represented by a light-gray, clayey-limy silt. The content of radioactive elements was relatively low. For example, the concentration of thorium was 2.1 micrograms per gram, on the average, and of uranium, 0.37 micrograms per gram. Ionium was of the same order of magnitude as at Station 97 and about 30 times higher than at the Io-U equilibrium (Table 5).

The results, as depicted in Figure 3, show, on one hand, that the concentration of thorium depends on the amounts of iron and manganese, with the exception of the lower horizon; and, on the other hand, that ionium decreases regularly with the depth of the section, as expressed by the ratios Io:MnO, Io:Th, and Io:Fe_2O_3. Despite the scatter of the data, especially in the lowest horizons (in which the concentration of ionium becomes so low that its reliable determination is practically impossible) the rate of sedimentation may be estimated sufficiently reliably. This rate is 1 cm per 1600 years.

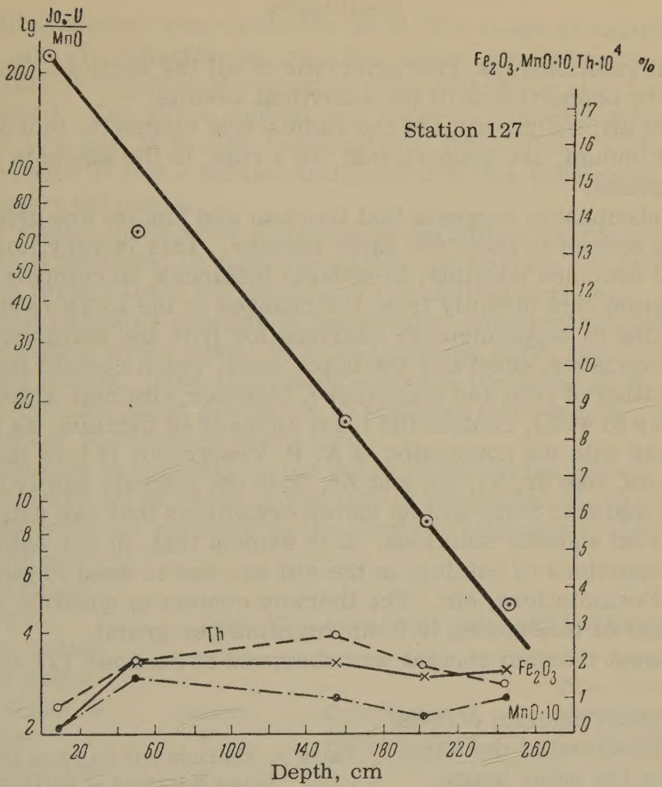

Fig. 3. Ionium, thorium, iron, and manganese in section at Station 127.

Table 5. Content of Th, U, Io, MnO, Fe_2O_3 in Section at Station 127

epth of izon, m	Th micrograms/gram	Io*	U	MnO %	Fe_2O_3 %	(Io-U): MnO	(Io-U): Fe_2O_3	(Io-U): Th
-10	0.04	11.0	0.2	0.05	0.8	216	1.3	27
-50	2.2	12.0	-	0.18	2.23	65	5.2	5.3
-164	2.8	2.4	0.36	0.13	2.07	15	0.9	0.7
-210	2.0	1.3	0.54	0.086	1.75	8.9	0.43	0.38
-250	1.6	1.1	0.38	0.15	0.91	4.5	0.37	0.45

uranium units

DISCUSSION

Several relationships, characteristic of all the sections, may be established by comparisons of the analytical results.

First of all, the amounts of the radioactive elements, thorium, uranium, and ionium, are proportional, as a rule, to the amounts of iron and manganese.

This relationship suggests that thorium and ionium are deposited on the sea bottom in about the same manner. This is very important because it becomes possible, in several instances, to compute the sedimentation rate directly from the changes in the Io:Th ratio, without resorting to supplementary analyses for iron and manganese.

Those horizons, generally the upper ones, which contain insignificant quantities of iron and manganese, together with high amounts of calcium (up to 40%), contain the least amounts of thorium, as a rule. This agrees with the conclusion of A. P. Vinogradov [4], to the effect that thorium, like Sc, Ti, Hf, and Zr, does not migrate easily in the biosphere and that there are no known organisms that can extract thorium from aqueous solutions. It is evident that, in our case, the higher proportions of calcium in the silt are due to dead organisms, diatoms, Foraminifera, etc. The thorium content in question is very close to that of limestones (0.5 micrograms per gram).

The lowest thorium content was observed at Stations 127 and 103 (Table 6).

The highest calcium content was also observed at the same stations, in the same upper horizon.

We should note here that thorium was relatively high in the intermediate horizons, namely about 7 to 10 micrograms per gram (Stations 97, 107, 17; the lower horizons). This is very close to its amount in terrestrial sediments, i.e., about 10 micrograms per gram in soils and 13 micrograms per gram in clays.

Table 6. Thorium and Calcium Content of Upper Horizons of Sections

Station No.	Th micrograms/gram	Ca,%
127	0.4	48
103	0.4	6.0
97	1.7	40.8
107	2.8	0.5

Uranium was very low in all sections, ranging from 0.1 - 0.3 to 1 micrograms per gram, with the exception of Station 17, where it was about 2 micrograms per gram. Ionium (in the upper horizons), in uranium units, was about 30 to 40 times higher than its uranium-equilibrium concentration, which is about 1.8 x 10^{-10} grams per gram.

Unfortunately, we had no horizons representing the sediment-water interface, either in the sections or in the scooped samples and all of our results refer to the 5 to 10 cm horizon. It is possible that in the surface layer all thorium and particularly all ionium concentrations would be higher by about 30%.

The silica content was within the 50 to 70% range at sampling sites 3, 107, and 17, reflecting the fact that those samples were collected the region of clayey-diatomaceous silts, where the clay fraction redominated. The silica content was lower at sampling sites 127 and 7—7.4 to 15% and 18 to 40% respectively. Site 127 had a clayey-limy haracter; site 97 had a foraminiferous silt with a substantial admix- re of clayey particles.

On the whole, there were appreciable variations in iron and man- anese in all sections, on transition from one horizon to another, with tendency toward their enrichment in the central horizons. This henomenon indicates changes in the physico-chemical environments sedimentation which began 10 to 20 thousand years ago, in the uaternary period. This conclusion supports the ideas of W. Schott to e effect that the latest glaciation in southern latitudes took place pproximately 20 thousand years ago.

Comparisons of our data on the rates of deposition show a definite ndency toward an increase in the rate of deposition of marine silts, we pass from the northern to the southern latitudes (Table 7).

Thus the sedi- entation rates the central rt of the Indian cean are about lf the values of ose in the uthern latitudes the same ocean. owever, five dimentary sec- ons are not ough for broad neralizations. rther studies this direction are continuing.

Table 7. Sedimentation Rates of Silts, Indian Ocean

Station No.	Coordinates at Sampling Sites		Time (in years) for deposition of 1 cm of sediment
127	30°42' S	60°42' E	1600
97	40°32' S	120°35' E	2000
103	50°21' S	110°12' E	1600
107	50°48' S	90°54' E	1100
17	60°25' S	90°48' E	830

In conclusion, we take this opportunity to thank A. I. Lisitzyn for acing the sedimentary sections at our disposal, and P. L. Bezrukov r consultation and for examining our materials.

CONCLUSIONS

The radiochemical studies here reported together with the results other investigations [5, 6, 7, 8], of the deep-sea oceanic sediments, ready permit certain definite conclusions:

a) The precipitation of thorium isotopes with marine sediments is e not only to a chemical co-precipitation (Indian Ocean) [5], but also adsorption by the active surfaces of the fine-sized clayey particles acific Ocean), as is indicated by comparisons between sesquioxides d the radioactive isotopes in the sediments.

b) It has been observed that the thorium content of all sections collected in the Pacific Ocean [5] is constant.

c) The ionium-uranium ratio fluctuates in vicinity of the equilibrium values, in samples of the bottom sediments collected not too distant from the coast. This fact shows that the ionium method of determining the rate of sedimentation is not suited for the near-shore sediments. On the whole, the method in question is not suited also for determining sedimentation rates wherever these rates are high [6].

d) The method in question gives the best results for sections collected far away from the shore, where sedimentation is not dominated by the coastal erosion. The radioactive isotopes are precipitated in such environments in proportions that are markedly different from the equilibrium proportions and the ionium-uranium ratio in the sediments may be as high as 10 - 20 [6].

e) The calculated rates of sedimentation of marine silts (uncorrected for the sampling disturbance) are 1 cm per 350 to 1000 years for the margins of the Pacific Ocean and 1 cm per 1600 to 2000 years for silts of the Indian Ocean.

f) Additional empirical data must be sought in further studies, for the determination of sedimentation rates, inquiries into the mechanisms of sedimentation, discovery of new relationships, and so on.

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CESIUM-RUBIDIUM MICROCLINE-PERTHITE AND ITS RARE ALKALI METAL CONTENT

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Abstract

The lithium, rubidium, and cesium contents of microcline-perthites of the la Peninsula, Russia, were studied using emission spectroscopy. The micro-ne-perthite, which is white or cream colored, developed during the magmatic age of pegmatization and was strongly albitized during a later metasomatic age. X-ray interplanar distance differences between microline-perthites con-ning 0.1% Rb and 1.4% Rb are only in intensity and number of lines. Spectro-emical data on Li, Rb, and Cs content of these perthites are given as a function depth (to 55.60 meters) for 17 samples. Lithium content is erratic and varies m 0.014% to 0.039%. Rb and Cs are present in higher concentrations than re-rted in other areas of the world; Rb: 1.08 - 1.6% and Cs: 0.11 to 0.14%. The neral is therefore called a rubidium-cesium microcline-perthite. A decrease Rb content with depth is claimed, which may be ascribable to varying degrees albitization of the microcline. Cesium remains practically constant over the me depth range. The green color of amazonite is not caused by its rubidium ntent. A table lists Li, Rb and Cs content of 26 amazonites, microclines, and crocline-perthites from Russia, United States (Colorado), Madagascar, and rway.

Much work has been done on the rare alkali metals in potassium dspars.

The presence of rubidium and cesium in amazonites was first es-lished by V. I. Vernadskii in 1909-1911 [3, 4]. He found 3.12% Rb_2O the amazonite from the Ilmen Mountains (Urals) and accordingly he lled this mineral "rubidium amazonite" [5]. The high rubidium and sium content in amazonites from Utõ Island, Sweden, and from Mada-scar was demonstrated by V. M. Goldschmidt and co-workers in 34 [6]. Yu. M. Tolmachev and A. N. Filippov [9, 10] published many ectrographic determinations of rubidium and cesium in microclines d their varieties (amazonites) from different sources. They found eater amounts of rubidium in the Ilmen Mountains and the Madagas-r amazonites. N. P. Kapustin, in 1939, found amazonites from the nen National Preserve high in rubidium and attempted to correlate or of the mineral with its rubidium content [8]. All these investi-ors believed that the high amounts of rubidium are characteristic only of amazonite. In 1942 O. J. Adamson reported high rubidium and cesium concentrations in the white microcline-perthites from Varuträsk, Sweden. Their average Rb_2O content was about 2%, with an average Cs_2O concentration of about 0.5%. Adamson called these minerals "cesium microcline-perthites" [1]. Appreciable quantities of rare alkalies were discovered by T. F. Borovik-Romanova and A. F. Sosedko [2] in the microclines and microcline-perthites from several pegmatite veins in the Kola Peninsula. Presence of rubidium in microclines and microcline-perthites from alaskites of Northern Kirgizia was noted by S. D. Turovskii [11]. E. N. Eliseev took issue with some other investigators and concluded that the green color of amazonite is not related to the presence of rubidium [7].

The present report deals with our studies of rubidium-cesium microcline-perthite from one of the pegmatites of the Kola Peninsula and with the distribution of rare alkali metals in this mineral.

The pegmatite body we studied has an irregular shape, including cupolas, pinch and swell structures, and apophyses. The body is traceable for 200 to 250 meters along its northwesterly extent. Down dip the vein was intersected by drilling at a depth of 300 meters.

Two stages of pegmatization are recognizable in the pegmatite body: the magmatic and the metasomatic. During the first stage, the following minerals were crystallized from the residual granitic melt: black tourmaline, albite-oligoclase, quartz, and microcline-perthite. During the metasomatic stage in the development of the pegmatite, there was replacement of microcline-perthite and formation of montebrasite, albite, quartz, manganian tantalite, pollucite, pink and multicolored tourmaline, etc. by solution processes. There were no changes in the mineral composition of the vein in depth.

Microcline-perthite constitutes a considerable part of the bulk of the pegmatite. This is chiefly in the blocky microcline-perthite zone, where individual blocks of microcline-perthite may be several cubic meters in size. The microcline-perthite is generally white, with a creamy shade. It is pink or flesh-red only in isolated areas. The mineral has a glossy luster and perfect cleavages, (001) and (010), with a hardness of about 6.5. The specific gravity of the microcline-perthite used in our study is 2.6327 *(sic)*. Locally, the microcline-perthite contains some quartz in the form of 1) fine grains, 2) small, rare irregularly shaped areas up to 1.5 x 2 cm in size, and 3) isolated intergrowths of elongated quartz up to 0.8 cm in length. The microcline-perthite is strongly albitized throughout the pegmatite body. Weakly albitized or unaltered areas are rare. Four types of albitization are recognizable: 1. Replacement of microcline by albite in the form of perthitic intergrowths. 2. Replacement of microcline by medium-grained albite. 3. Replacement of microcline by cleavelandite. 4. Replacement of microcline by sugary albite.

Veinlets of albite, quartz, spodumene, and muscovite, in a microscopically small (0.8 mm) to appreciable (0.8 meters and larger) size range, are present in the microcline-perthite. Thin sections show

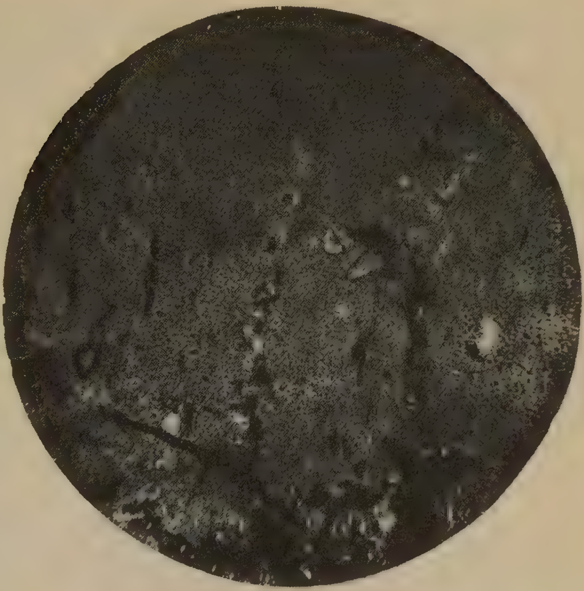

Fig. 1. Veinlets of quartz and albite with muscovite and spodumene (crossed-nicols; magnification 35 X).

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nted by Ab_7An_3 - Ab_8An_2, is seen both as fine discontinuous veinlets,
ngated in the same direction as scattered dots and small irregularly
aped areas. This albite intergrowth is represented by polysyntheti-
lly twinned replacement perthites. The twins are situated at right
gles to the direction of elongation of the perthitic intergrowths. The
ical axis angle in microcline-perthite from different parts of the
gmatite body varies from 77 to 82°. The extinction angle is 16 to
on the (001) cleavage plane. O. J. Adamson believes that this angle
somewhat larger in rubidium microclines than in ordinary micro-
nes, which is about 17°.

For sake of comparison, we present here X-ray data for a high
bidium microcline-perthite (1.4% Rb) and for a low rubidium micro-
ne-perthite (0.1% Rb) from a pegmatitic body which contains no
re-metal mineralization.

Table 1 shows that the only differences between the diffraction pat-
ns of the high rubidium and the low rubidium microcline-perthites
in the intensity and number of the lines. The interplanar distances
our specimens vary only within hundredths of one angstrom unit.
X-ray diffraction patterns were obtained by Prof. E. S. Makarov
he V. I. Vernadskii Memorial Institute of Geochemistry and Ana-
cal Chemistry, Academy of Sciences of the USSR, to whom we ex-
d our sincere thanks.

Table 1. Interplanar Distances λ_{Cu}; 2R = 57.3 mm; d = 0.6 mm; exposure 3.5 hours

Line No., in sequence	Microcline-perthite 0.1%Rb		1.4%Rb		Line No., in sequence	Microcline-perthite 0.1%Rb		1.4%Rb	
	I	d	I	d		I	d	I	d
1	3	4.28	4	4.28	40	3	1.31	5	1.31
2	1	4.03	3	3.96	41	3	1.28	5	1.29
3	2	3.38	-	-	42	3	1.26	5	1.27
4	-	-	6	3.73	43	-	-	4	1.25
5	1	3.64	2	3.58	44	-	-	4	1.21
6	4	3.50	-	-	45	4	1.19	3	1.19
7	7	3.40	3	3.42	46	-	-	4	1.17
8	-	-	9	3.30	47	-	-	4	1.15
9	10	3.23	9	3.20	48	2	1.14	5	1.14
10	1	2.99	6	2.95	49	3	1.13	4	1.12
11	1	2.88	5	2.88	50	1	1.09	5	1.11
12	5	2.79	4	2.74	51	1	1.08	4	1.08
13	4	2.65	-	-	52	-	-	3	1.07
14	2	2.52	8	2.54	53	-	-	3	1.06
15	2	2.41	4	2.40	54	0.5	1.04	2	1.04
16	3	2.39	3	2.30	55	-	-	2	1.036
17	0.5	2.23	-	-	56	1	1.01	2	1.022
18	9	2.16	2	2.14	57	2	0.981	2	1.005
19	0.5	2.13	7	2.12	58	1	0.963	6	0.966
20	5	1.99	2	2.05	59	-	-	4	0.957
21	-	-	2	2.02	60	2	0.938	4	0.941
22	-	-	4	1.97	61	-	-	3	0.933
23	3	1.92	3	1.92	62	-	-	4	0.927
24	5	1.85	2	1.87	63	1	0.915	5	0.912
25	10	1.80	3	1.84	64	1	0.907	4	0.908
26	-	-	10	1.78	65	-	-	5	0.897
27	2	1.74	2	1.74	66	1	0.889	3	0.888
28	2	1.65	3	1.69	67	-	-	5	0.873
29	-	-	3	1.66	68	1	0.865	4	0.862
30	1	1.61	4	1.63	69	1	0.858	3	0.8506
31	-	-	3	1.57	70	2	0.843	4	0.848
32	4	1.56	5	1.56	71	-	-	4	0.839
33	5	1.50	-	-	72	2	0.829	4	0.828
34	1	1.47	6	1.45	73	2	0.819	-	-
35	4	1.45	6	1.45	74	2	0.808	3	0.808
36	4	1.42	6	1.43	75	-	-	4	0.802
37	4	1.40	4	1.40	76	-	-	3	0.797
38	2	1.37	4	1.38	77	2	0.794	4	0.796
39	-	-	4	1.33	78	1	0.783	3	0.787

Quantitative spectrographic analysis of the specimen*, by T. F. Borovik-Romanova of the same Institute, gave the following results: 0.026% lithium, 1.27% rubidium, 0.10% cesium.

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*Presumably sample #9, Table 3.

By re-calculating the chemical analysis to microcline and albite,
ır specimen was found to be 81.47% microcline and 17.52% albite.
he percentage composition of the microcline was calculated as 62.04%
O_2, 20.40% Al_2O_3, and 17.55% K_2O (Table 2).

Table 2. Re-Calculation of Chemical Analysis of Rubidium-high Microcline

			Microcline		Albite	
xides	% by weight	Molecular proportions	Molecular proportions	% by weight	Molecular proportions	% by weight
O_2	62.10	1034	842	50.55	0192	11.55
iO_2	trace	-	-	-	-	-
l_2O_3	19.83	0194	162	16.62	0032	3.21
e_2O_3	0.09	-	-	-	-	-
aO	0.30	0005	-	-	0005	0.30
gO	0.06	-	-	-	-	-
nO	0.00	-	-	-	-	-
$_2O$	14.30	0152	152	14.30	-	-
a_2O	2.46	0032	-	-	0032	2.46
$_2O^-$	0.13	-	-	-	-	-
$_2O^+$	0.45	-	-	-	-	-
Sum	99.72			81.47		17.52

We analyzed for rubidium, cesium, and lithium in microcline-
rthites from different parts of the pegmatite, so as to follow the
lationships of distribution of these alkali metals within a pegmatite
dy. Li, Rb, and Cs were determined quantitatively by the spectro-
aphic method; results are shown in Table 3. The analyses were
ade in a glass 3-prism spectrograph ISP-51 with an F = 270 mm
mera. The image of the arc was projected onto the slit of the
ectrograph by a system of two lenses, with an inserted diaphragm.
ıe width of the slit was 0.02 mm; the height of the diaphragm - 3.2
m. A two-stage filter was placed in front of the slit by which the
tensity of the spectrum was reduced 3-fold in the second stage. The
ost sensitive lines of Rb and Cs were chosen for the analysis: Rb
00.23 and 7947.60 Å; Cs - 8521.11 Å. Lithium was determined by
e 6103.64 Å line. The 6707.84 Å lithium line could not be used be-
use the Li content in all samples was hundredths of one per cent
fficient for strong self-absorption of the 6707.84 Å line. The spectra
re photographed on the infra-red sensitive film 840 (for Rb and Cs)
d "infra-chrom" film 760 (for Li).

An activated AC arc with carbon electrodes was employed as the
citation source. A complex electrode was used, consisting of the
llar and platform. The cavity in the upper part of the collar was
5 mm in diameter and 4 mm deep. Powdered carbon was first

Table 3. Rubidium, Cesium, and Lithium in Microcline-Perthite at Different Depths of the Pegmatite Body

Sample No.	No. of Trench and Bore-hole	Depth in meters	Weight Per Cent		
			Rubidium	Cesium	Lithium
1	1k	2.00	1.6	0.12-0.22	0.039
2	1	10.80	1.34	0.12	0.026
3	2	12.50	1.08	0.11	0.014
4	2	14.50	1.41	0.14	0.020
5	2	16.50	1.28	0.12	0.021
6	2	19.25	1.22	0.14	0.024
7	3	23.05	1.17	0.12	nd
8	3	24.50	1.43	0.13	0.025
9	4	24.90	1.27	0.10	0.026
10	3	26.0	1.20	0.14	nd
11	5	31.75	1.08	0.13	0.020
12	6	34.75	1.17	0.11	nd
13	7	35.30	1.10	0.11	nd
14	7	38.35	1.21	0.12	0.033
15	8	38.60	1.26	0.15	0.014
16	9	54.30	1.20	0.13	0.015
17	9	55.60	1.20	0.13	nd

poured onto the bottom of the cavity and was tamped down with a metallic rod, whereupon 0.015 g. of the sample was placed on top of the tamped-down carbon; this charge was covered by powdered carbon, in order to avoid losses by expulsion on arcing. These precautions were conducive to complete and rapid volatilization of the sample with a minimum of fusion. The arc was fed by 220 V, 7 amp. alternating current. The exposure was 5 minutes.* Rare alkali metal content was evaluated by the 3-point reference method. Calibration curves were constructed with "log c" and "Δ S" as coordinates, where "c" is the concentration of the element sought and "Δ S" is the difference between the density of the test line of the element sought and adjoining background. The calibration curves were straight lines within the following range of the concentrations: 0.7 to 0.05% Rb; 0.02 to 0.5% Cs; 0.015 to 0.5% Li (Figures 2 and 3). The samples were diluted 3-fold with albite containing no Li, Rb, or Cs, because their original Rb content was about 1%. The determination of Li required no dilution in the majority of cases. The standards were made of microcline containing known amounts of Li, Rb, and Cs. The weak standards were made by 3-fold dilution of the stronger ones with albite.

The relative error of the method (the arithmetical mean), as determined by repeated measurements, was ± 7.0% for Rb, ± 9.3% for Cs, and ± 10.5% for Li.

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*This is an unusually long arcing period.

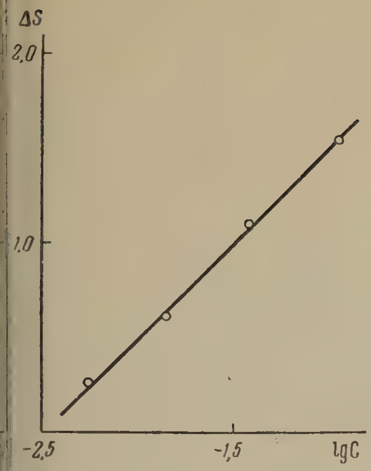

Fig. 2. Calibration curve for Determination of Lithium in Microcline by the 6103.6 Å Line.

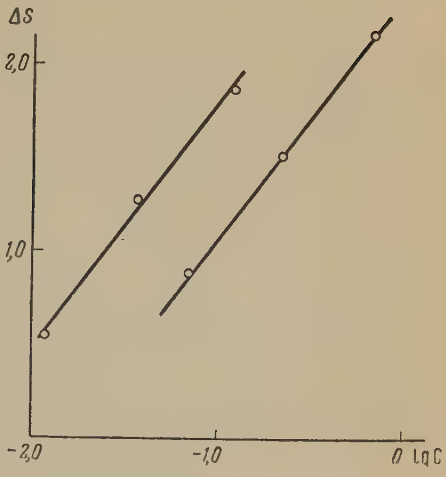

Fig. 3. Calibration curve for Determination of Rubidium and Cesium in Microcline by the 7800.3 Å and the 8521.1 Å Lines Respectively.

As shown in Table 3, the highest rubidium content in microcline-perthites of the pegmatite body is 1.6, 1.34, and 1.41%, found at depths of 2.0, 10.80, and 14.50 meters respectively.* Rubidium is somewhat lower (1.17 to 1.10%) at depths of 23.05, 31.75, and 35.30 meters. At 55.6 meters below the surface, the rubidium concentration is 1.20%. Cesium occurrences have been recorded in the entire interval, beginning with a depth of 1.0 to 55.60 meters from the surface. The cesium content is practically constant (0.11 to 0.14%) in all samples of the microcline-perthite examined. There are only minor departures from this range; for example, 0.12 to 0.22% Cs at a depth of 2.0 meters and 0.15% Cs at 38.60 meters.

Rubidium and cesium replace potassium isomorphously in all potassium feldspars, including microcline-perthites. This isomorphous replacement is due to the similarity of their sixfold coordinated ionic radii: K = 1.33, Rb = 1.49, and Cs = 1.65 Å. Variations in the rubidium content of microcline-perthites from different depths are due to the different degrees of albitization of the microcline, as is made clear both by macroscopic and microscopic studies. There is nothing regular about the distribution of lithium in microcline-perthite. The Li content varies from 0.014 to 0.026% and in isolated cases may be as high as 0.033%. Lithium does not replace potassium isomorphously because of its relatively small ionic radius (0.78 Å). It is present in microcline-perthites probably as a mechanical

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*and 1.43% Rb at 24.50 meters. (Editor)

Table 4

Sample No.	Mineral	Source	Weight Per Cent			Authority
			Rb	Cs	Li	
1	Amazonite	Ilmen Mts., Urals	1.3	0.05	-	Yu. M. Tolmachev and A. N. Filippov [9, 10]
2	''	Nat'l Preserve, Urals	0.7	0.03	-	
3	''	Inporr, Khibina, Tundra	0.2	0.05	-	
4	''	Colorado, USA	0.2	0.005	-	
5	''	''	0.1	0.003	-	
6	''	Madagascar	0.1	0.15	-	
7	Microcline	Ilmen Mts., Urals	0.01 to 0.1	0.0001 to 0.01	0.0001 to 0.001	
8	''	Vishnevye Mts., Urals	0.001 to 0.1	0.001 to 0.01	0.0001 to 0.001	
9	''	Khibina	0.01 to 0.1	0.001 to 0.01	0.0001 to 0.001	
10	''	Sliudianka, Transbaikal	0.001 to 0.1	0.001 to 0.1	0.0001 to 0.001	
11	''	Altai	0.001 to 0.01	-	0.0001 to 0.001	
12	''	Karelia	0.001 to 0.1	0.001 to 0.1	0.0001 to 0.001	
13	Microcline-perthite	Ilmen Mts., Urals	0.001 to 0.01	- -	0.0001 to 0.001	
14	''	Central Asia	0.01 to 0.1	0.001 to 0.01	0.0001 to 0.001	
15	''	Sliudianka, Transbaikal	0.001 to 0.1	0.001 to 0.01	0.0001 to 0.001	
16	''	Norway	0.01 to 0.1	0.001 to 0.01	0.0001 to 0.001	
17	Microcline-perthite	Kola Peninsula	1.08 to 1.6	0.11 to 0.22	0.014 to 0.039	T. F. Borovik-Romanova and E. D. Kalita (this paper)
		Northern Kirgizia				
18	Microcline and Microcline-perthite from alaskites	1. Kastetsk Range	0.06			S. D. Turovskii [11]
19		''	0.13			
20		''	0.27			
21		''	0.30			
22		''	0.53			
23		2. Dolpran	0.22			
24		3. Kiperli-Sai	0.35			
25		''	0.015			
26	Microcline from quartz porphyry	4. Kastetsk Range	0.60			

mixture. The lithium "highs" in microcline-perthites in some rts of the pegmatite may be explained by the presence of some icroscopic inclusions of spodumene and other lithium minerals.

Thus rubidium is present in very high quantities at the surface and depth down to 55.60 meters in the microcline-perthites of the peg- atite body, whereas cesium is significantly less abundant.

Some published data on the rare alkali content of amazonites, mi- roclines, and microcline-perthites from different sources are cited re for comparison (Table 4).

The microcline-perthite from the pegmatite of the Kola Peninsula characterized by the highest content of rubidium and cesium, as ay be seen in Tables 3 and 4. Our comparisons and data of E. N. iseev [7] and O. J. Adamson [1] do not confirm the hypothesis that lors of amazonites are due to the presence of rubidium.

The following conclusions may be drawn from the results of our vestigations:

1. Rubidium and cesium "highs" are present in microcline- rthites from a pegmatite body in the Kola Peninsula. Rubidium is ost abundant (1.08 to 1.60%). Cesium is found in appreciable quan- ies (0.11 to 0.14%), many times higher in microcline-perthites than om other areas. Because of the high amounts of these elements in e microcline-perthites here investigated, these minerals may be lled "cesium-rubidium microcline-perthites."

2. There is a certain relationship between depth and abundance of bidium in the microcline-perthites. Rubidium tends to gradually crease with depth. As for the cesium content of microcline- rthites, it remains practically the same throughout the correspond- g depths.

3. Our findings and the comparisons of data on rubidium in micro- ine-perthites and amazonites from different sources, as well as the sults of O. J. Adamson [1] and E. N. Eliseev [7] do not confirm the ppositions of V. M. Goldschmidt [6] and N. P. Kapustin [8] to the fect that the green color of amazonite is due to the presence of bidium.

The authors thank A. P. Vinogradov and E. E. Kostyleva for their luable suggestions and aid in this work.

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EDITORIAL COMMENT

The cause of green color in amazonite is the subject of considerable literature. Germane to this study is Bassett's paper (1956) which rules out Cu, Ni, Cr, V, as well as Rb, as being responsible for the green coloring of amazonite. Bassett considers a ferrous feldspar, $FeAl_2Si_2O_8$, as a possible color source. As with the case for lithium (Rankama and Sahama, 1950, p. 140), ferrous iron in pegmatite feldspars may afford an example where a feldspar structure may contain small quantities in solid solution of a compound ($FeAl_2Si_2O_8$) which is not stable alone. The calculated heat of formation of both hypothetical feldspar compounds, $LiAlSi_3O_8$ and $FeAl_2Si_2O_8$, are + 35 and + 44 kcal/mol respectively. This positive ΔH would indicate their thermodynamic instability and preclude formation or existence of these compounds other than, perhaps, in solid solution. On the other hand, the calculated heats of formation (ΔH) of Rb, Cs, and K feldspars are all pegative (-130, -145, and -117 respectively) indicating a likelihood of formation of stable feldspar structures (Schiebold, 1931).

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SOME PECULIARITIES IN THE DISTRIBUTION OF LITHIUM AND RUBIDIUM IN CERTAIN GRANITOIDS OF YAKUTIA

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Abstract

Data on the lithium and rubidium contents in some granitoids of the Yakutia utonomous Soviet Socialist Republic are presented in the article. An increase the lithium and rubidium contents in case of a transition from granites and amellites to later rocks (alaskites) is noted. The lithium and rubidium con- ntrations also increase noticeably if later processes (greisenization) are perimposed on the rock.

The Arga-Ynnah-Khaya granitoid body in Yakutia is composed of arse-grained porphyritic two-mica granites and of fine- to medium- ained biotite adamellites. The adamellites in the central part of the dy are cut by alaskites and by fine-grained leucocratic tourmalin- ed granite-aplites which are the late-differentiated fractions of the anitic magma, according to A. A. Sukharina (oral communication).

The alaskites of the Arga-Ynnah-Khaya are characteristically gher in lithium and rubidium than the other rocks. They are in a finite contact with the adamellites in the west and with the tourma- nized granite-aplites in the northwest.

The bulk of the alaskites is essentially of one and the same type, oth in appearance and in composition. The alaskites are essentially ne-grained, light-colored rocks consisting chiefly of quartz, albite, uscovite, and potassium feldspar. Amblygonite, cassiterite, apatite, hene, and other minerals are present in insignificant quantities. ocally, the alaskites are somewhat enriched with respect to lepidolite d amblygonite.

The alaskites are severely greisenized and albitized near their ntact with the adamellites. There are also some areas, locally, here the altered alaskites are represented by a kaolinized clayey ass.

The greisenized alaskites, in contrast with those not greisenized, e characterized by a significant development of fine veinlets of pale- ay quartz. Concentrations of stannite and of its alteration products e noticeable in these quartz veinlets.

The introduced concretionary phosphates (apatites and others) are und in the same place, in the small cavities in greisenized alaskites.

The larger cavities contain concentrations of augelite crystals and, fairly commonly, druses of light-gray quartz and, more rarely, of smoky quartz.

Among the granitoids here examined, we observe also the vein facies of the alaskites which is represented by a series of albitized alaskite dikes, up to several meters thick and a few hundreds of meters long.

The dikes are composed of a medium- and fine-grained rock whose principal minerals (potassium feldspar, albite, quartz, and others) do not exceed a few millimeters in size. The dikes contain also amblygonite, muscovite, cassiterite, pyrite, apatite, and some other minerals in insignificant quantities.

In his studies of the Arga-Ynnah-Khaya granitoids, the author had collected samples of granites, adamellites, tourmalinized granite-aplites, greisenized and non-greisenized alaskites, the

Table 1. Complete Chemical Analyses of Adamellites and Alaskites (average samples)

Oxides	Adamellites[a] % by weight	Alaskites[a] % by weight	Greisenized Alaskites % by weight
SiO_2	69.48	65.15	66.39
TiO_2	0.36	0.47	Trace
Al_2O_3	18.39	20.88	20.73
Fe_2O_3	0.10	0.02	0.42
FeO	-	-	-
MnO	Trace	0.05	0.06
MgO	0.25	0.22	0.16
CaO	1.19	0.21	1.20
SrO	-	-	-
BaO	-	-	-
Na_2O	2.89	8.24	3.34
K_2O	5.08	1.02	3.52
P_2O_5	-	2.05	-
H_2O^-	0.28	0.07	0.27
H_2O^+	1.05	0.59	1.32
Loss on ignition	0.48	0.51	0.86
Li_2O	0.09[b]	0.44	0.56
Rb_2O	0.08[c]	0.24[c]	0.25 to 0.33
SnO_2	Not determined	Not determined	0.10
F	-	-	0.77[c]
Sum	99.72	100.17	100.03 - 0.32 = 99.71
Analyst and date	Z. Burova 1957	O. Dorondova 1957	T. Kapitonova 1957

a. Judging by the analyses, both adamellites and alaskites had been altered (potassium is high in adamellites, and sodium in alaskites).

b. By the flame photometer, at the IMGRE*; E. A. Fabrikova, Analyst; reliability ±7%.

c. By the quantitative spectrographic method, at the IMGRE*; L. D. Sazhina, Analyst; reliability ±10%.

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ke series of the alaskites,
d altered zones of the alas-
te body. The samples were
ken by breaking the rock with
e hammer. The weight of
ery sample was about 10 kg.
veral adamellite and alas-
te samples were analyzed
emically at the Institute of
ineralogy, Geochemistry, and
rystal Chemistry, Academy
Sciences of the USSR, the
IGRE (Table 1).

The lithium content (rubi-
um was not determined) was
scertained for the rest of the
mples by E. A. Fabrikova,
the flame-photometric pro-
dure (Table 2).

For the sake of clarity, the
i_2O and Rb_2O contents of the
rga-Ynnah-Khaya rocks are
presented graphically as
igure 1.

Lithium is associated chief-
with biotite, in granites and
lamellites. Lithium in alas-
tes is fixed in amblygonite
d, to a lesser degree, in
uscovite. In greisenized
askites, the bulk of lithium
in amblygonite and in the
icas. In altered alaskites,
thium accumulates in the
ayey mass.

Rubidium, as we know, is
osely tied to potassium, geo-
emically. The accumulation
rubidium in alaskites, as
gainst adamellites, takes place
iefly at the expense of the
icas.

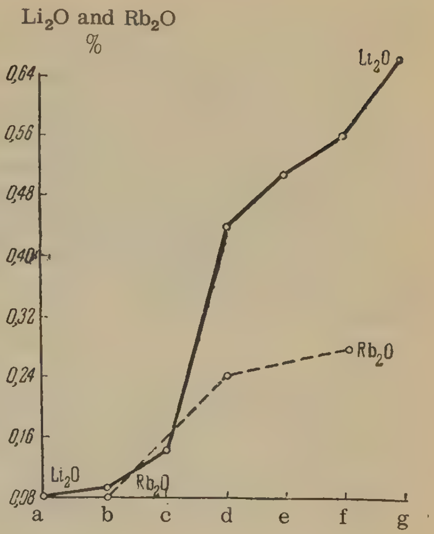

Fig. 1. Li_2O and Rb_2O in Arga-Ynnah-Khaya granitoids: a—granites; b—adamellites; c—tourmalinized granite-aplites; d—alaskite body of crystalline rock; e—alaskite dikes; f—greisenized alaskite body of crystalline rock; g—zone of alteration of the alaskite body.

Table 2. Lithium Content of Granites, Tourmalinized Granite-Aplites, Alaskite Dikes, and the Zone of Altered Alaskites

Rock	LiO_2 %
Granites	0.08*
Tourmalinized granite-aplites	0.14
Alaskite dikes	0.51
Zone of altered alaskites	0.66

*Reliability ±7%

CONCLUSIONS

1. There is a marked increase in the content of lithium and rubi-
um on transition from the earlier rocks (granites, adamellites) to

the later rocks (alaskites). In this case the Li_2O content increases 6 to 7 times and the Rb_2O content 3 times.

2. The concentrations of lithium and rubidium increase also following the subsequent imposition of the greisenization process upon the rock. The Li_2O content of the greisenized alaskites was increased by 27%, as against the non-greisenized alaskites, and the Rb_2O content by 14% (which is the maximum).

3. The lithium content (rubidium was not determined) increases (0.66% Li_2O) in kaolinized areas of the alaskite body (adsorption by clay minerals), in comparison with its amounts in the body itself (0.44 to 0.52% Li_2O).

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MOLYBDENUM CONTENT OF CERTAIN ROCKS AND MINERALS IN THE INTRUSIVES OF EASTERN TRANSBAIKAL

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Abstract

The molybdenum content in investigated unaltered magmatic rock varieties the Eastern Transbaikal ranges from 0.5 to 3 micrograms. Molybdenum in-eases from older to younger units in each of the examined intrusive complexes. w molybdenum contents have been noted in feldspars, in biotite and in horn-endes (from 0.5 to 1 microgram). The highest content has been established in menites, magnetites and especially in sphenes (up to 400 micrograms).

More than six hundred determinations of molybdenum in rocks and 6 determinations of this element in different granitoids of Eastern ansbaikal were performed, for the sake of obtaining data on the dis-bution of individual elements in magmatic formations, in order to certain geochemical characteristics of ore-bearing complexes.

We assembled materials from three different metallogenic zones: polymetallic (the ore fields of Klichka and Kadaya and the Argun nge); b) molybdenum (Bugdaya, Shakhtama, and Sarygich deposits); tin-tungsten (Bukuka, Belukha, Aldakachan, Etyka, Malyy Soktuy, rulgui, Khapcharanga, and Khamara-Tyrin Bodies).

The crystalline bodies were spot-sampled individually, so as to llect large samples (8 to 10 kg) for examination of the accessory nerals. Duplicates of these samples were analyzed quantitatively, the spectrographic method developed at the VSEGEI * by M. M. er, Z. G. Timonina, and A. N. Muraveva.

Determinations of molybdenum in rocks were made by the ''method additions'' (A. N. Muraveva, Analyst). 40 to 50 milligram aliquots the test materials were volatilized completely from the cavities in rbon electrodes, in the AC arc at 200 V and at 20 amp. current. The cords were taken by the ISP-22 spectrograph. Films of Type II re used, with the 8-unit sensitivity, according to Gost. The charac-ristic sensitive line = 3170.3 Å was used for the estimations of olybdenum. Tungsten was the internal standard (λ = 2896.4 Å). producibility of the method was ± 16.5%.

Feldspars, biotites, hornblendes, magnetites, sphenes, and ilmenites re isolated from the rocks, for our studies of the distribution of olybdenum.

Vsesoyuznyi Geologicheskii Institut'' (All-Union Geologic Institute). VPS

Molybdenum in the minerals here listed was determined by the following procedure (M. V. Zhdanova, Analyst):

Finely pulverized aliquots of the mineral are fused with 5 times their weight of the sodium carbonate (10 parts) - sodium nitrate (1 part) flux. The fused mass is extracted with water, with the addition of a few drops of alcohol (to reduce Mn), if any noticeable amounts of manganese are present. After heating to boiling, the extract is filtered through paper and the insoluble residue is washed with several portions of hot aqueous sodium carbonate and with water.

The filtrate is made acid to litmus with H_2SO_4 (1:1), shaken gently, so as to expel CO_2, cooled, and transferred into a separatory funnel; the volume is made up to 50 mls.

1 ml of 50% tartaric acid is added, followed by 2 mls of 25% potassium or ammonium thiocyanate, and by 2 mls of 20% stannous chloride. The solution is mixed thoroughly after the addition of every reagent. Iso-amyl alcohol or some other organic solvent is added and shaking is continued for 1 minute, whereupon time is allowed for the separation of the two liquids.

If the molybdenum content is very low (1 to 5 micrograms), the extraction is done with 1 ml of the organic solvent. The organic solvent extracts are compared with standards treated and prepared in the same way.

A preliminary separation of molybdenum from iron is required in the analysis of magnetites, by the means of animal charcoal or of activated carbon.

An aliquot of magnetite is decomposed by aqua regia and the adsorption of iron and molybdenum is carried out at pH 3, in nitric acid solution. Molybdenum is de-sorbed by 2% NaOH, with heating. The solutions contain now only molybdenum, for all practical purposes, and are suited for the analysis by the procedure already described. The Table shows the average molybdenum content of rocks and minerals. The following conclusions may be drawn from our results:

1. The molybdenum content of rocks varies within a wide range, from 0.5 to 200 micrograms.* The higher concentrations of molybdenum are brought about by secondary post-magmatic processes, as expressed in silicification, sericitization, epidotization, pyritization, and by the presence of commensurable quantities of molybdenite.

Without taking into account the molybdenum anomalies associated with the secondary processes (the Bugdaya quartz porphyrites, the small Syrygichi intrusions, the effusives of the Argun Range, the Belukha granitoids, the crystalline bodies of Durulgui, Khapcheranga, and Khamar-Tyrin), we may assume that molybdenum ranges from 0.5 to 3 micrograms (per gram - VPS) in the magmatic acidic rocks of Eastern Transbaikal.

2. Wherever hydrothermal processes had been imposed upon magmatic bodies, there are wide variations in the molybdenum content in

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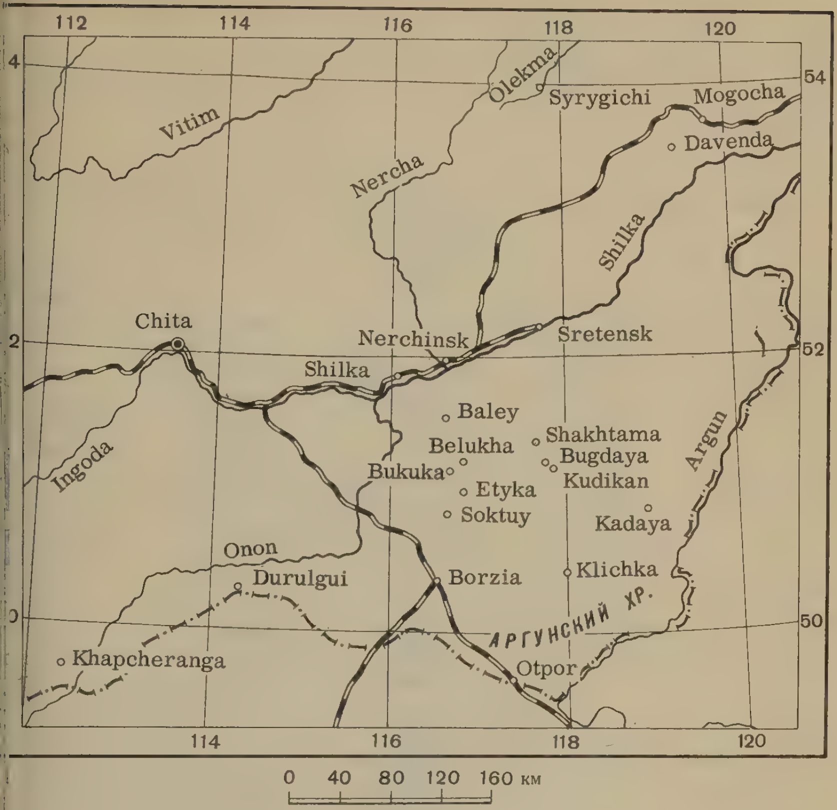
*Per gram; i.e. 0.5 to 200 ppm Mo. VPS



e and the same crystalline body of rock, here studied.

3. Small intrusions within the zone of molybdenum mineralization
e characteristically high in molybdenum (Bugdaya, Syrygichi). As
rule, such bodies are high in both molybdenite and pyrite.

4. Granodioritic bodies of the Shakhtama type (Shakhtama, Bugdaya)
d the young granodioritic intrusions of Syrygichi (definitely por-
yroid-like), which are associated paragenetically with molybdenum
neralization, are by no means distinguished by their higher molyb-
num content, while the more ancient complexes contain character-
ically the lowest amounts of this element.

It becomes possible therefore to assume that intrusions with which
molybdenum mineralization should be associated paragenetically,
geologic reasons, are not distinguished by any increases in their
lybdenum content.

5. Molybdenum content increases from the older to the younger
ks, within the boundaries of every magmatic complex, in this or
t ore zone. Thus in the acid effusives of Argun, we observe an
rease in molybdenum from the more ancient Jurassic banded

quartz porphyries (2.2 micrograms) to the younger Cretaceous quartz porphyries (5.3 micrograms).

The ancient alaskite granites of the Klichka Ore Field contain characteristically less molybdenum (0.7 micrograms) than the younger quartz diorites (1.4 micrograms).

Average Molybdenum Contents of Certain Rocks and Minerals from Eastern Transbaikal

Item	Source	No. of Analyses	Rock	Mineral	Mo content, Micrograms Per Gram
1	Bugdaya	12	Alenui granite	Whole rock	0.5
2	"	2	" "	Feldspar	1
3	"	3	" "	Sphene	80.8
4	"	6	" "	Biotite	Trace
5	"	15	Granodiorite (Shakhtama type)	Whole rock	1.5
6	"	4	"	Feldspar	?
7	"	2	"	Sphene	73.8
8	"	3	"	Biotite	1
9	"	1	"	Magnetite	10.5
10	"	12	Quartz porphyry	Whole rock	200
11	"	1	"	Feldspar	1
12	"	10	Quartz porphyry tuff	Whole rock	30
13	"	1	"	Feldspar	90
14	Shakhtama	10	Alenui granite	Whole rock	0.8
15	"	1	Granite porphyry	Feldspar	2
16	"	16	Granodiorite (Shakhtama type)	Whole rock	1.3
17	"	5	"	Sphene	187.1
18	"	1	"	Magnetite	2
19	"	10	Porphyrite	Whole rock	2.4
20	"	1	"	Feldspar	28
21	Kadaya	50	Carbonate beds	Whole rock	Not detected
22	"	35	Shales	" "	1.2
23	"	24	Porphyroid biotite-hornblende granodiorites	" "	1.5
24	"	3	"	Sphene	48
25	"	8	"	Feldspar	Not detected
26	"	2	"	Ilmenite	Trace
27	"	1	"	Magnetite	1.5
28	"	1	"	Biotite	Not detected

Average Molybdenum Contents of Certain Rocks and Minerals from Eastern Transbaikal (continued)

m	Source	No. of Analyses	Rock	Mineral	Mo content, Micrograms Per Gram
	Kadaya	30	Uniformly grained biotite-hornblende granodiorite	Whole rock	2.4
	"	1	"	Feldspar	Not detected
	"	5	"	Biotite	"
	"	9	"	Hornblende	Trace
	"	12	Granite-porphyry	Whole rock	0.9
	Kadaya	2	"	Feldspar	Not detected
	"	1	"	Biotite	"
	"	10	Quartz porphyry	Whole rock	1.9
	"	1	"	Feldspar	Not detected
	"	10	Porphyrite	Whole rock	1.6
	Klichka	144	Limestone and dolomite	Whole rock	Not detected
	"	41	Shales	" "	1.1
	"	10	Granite-gneiss	" "	2.3
	"	15	Alaskite granite	" "	0.7
	"	2	"	Feldspar	Not detected
	"	1	"	Biotite	"
	"	1	"	Magnetite	2
	"	20	Quartz diorite	Whole rock	1.4
	"	4	"	Feldspar	?
	"	9	"	Biotite	0.5
	"	4	"	Hornblende	1
	"	1	Porphyrite	Feldspar	?
	Argun Range	15	Banded qtz. porphyry	Whole rock	2.2
	"	12	Trachyandesite	" "	2.1
	"	12	Felsites and their tuffs (I_3)	Whole rock	3.3
	"	13	" (Cr)	" "	3.1
	"	15	Qtz. porphyries and their tuffs (Cr)	Whole rock	5.3
	Syrygichi	6	Olekma granite	" "	2.5
	"	5	Markedly porphyry-like granite	" "	4.1
	"	1	"	Sphene	291.6

Average Molybdenum Contents of Certain Rocks and Minerals from Eastern Transbaikal (continued)

Item	Source	No. of Analyses	Rock	Mineral	Mo content, Micrograms Per Gram
59	Syrygichi	7	Granite porphyries Quartz porphyries	Whole rock	8.2
60	"	2	"	Sphene	111.2
61	"	2	"	Magnetite	5.5
62	"	1	Amphibolite-biotite granodiorite	Sphene	34
63	"	1	Granodiorite	"	101.6
64	"	2	Biotite-hornblende granite	Sphene	73.5
65	"	1	Biotite granite	Magnetite	Not detected
66	"	1	Amphibolite-biotite granodiorite	"	1.5
67	"	1	Uniformly grained biotite granite	"	Trace
68	"	1	Granodiorite	Magnetite	0.8
69	Bukuka	20	"	Whole rock	1
70	Belukha	12	"	" "	6.6
71	"	13	Porphyry-like granite	" "	9.0
72	"	1	"	Ilmenite	328
73	Etyka	2	Amazonite granite	Whole rock	0.7
74	Malyy Soktuy	13	Biotite granite	" "	2.0
75	Durulgai	2	Porphyry-like granite	" "	3.8
76	Khapcheranga	6	Granite porphyry	" "	4.1
77	Khamaro-Tyrin	2	Biotite granite	" "	5.8
78	Zapokrovskoe	1	Quartz diorite	Sphene	256
79	Purinskii Pereval, Pereval, Aleks. Zavod	1	Granite	"	58
80	Akatui	1	Syenite-diorite	"	Not detected
81	"	2	"	Biotite	1.5
82	Borshchovochnyi Kriazh	1	Granite	Sphene	34
83	"	2	Porphyry-like granite	Biotite	0.5
84	"	1	"	Ilmenite	104

The intrusive complex of the Shakhtama-Bugdaya Ore Field is char- terized by the relatively low molybdenum of the ancient Alenui grani- ids (0.6 micrograms) and by the higher molybdenum of the younger anodiorites of the Shakhtama type (1.4 micrograms).

The relationship here suggested is particularly conspicuous in the trusive rocks of Syrygichi “Ore Center”.* The older Olekma gran- es are characterized by the lowest amounts of molybdenum, in com- rison with the younger definitely porphyry-like granites and porphyry anites of the “minor” intrusions (the Olekma— 2.5, the definitely rphyry-like—4.1, the granite porphyries—8.2 micrograms per gram).

6. No trace of molybdenum whatsoever is detectable spectrographi- lly in carbonate rocks (limestones, dolomites).

Shales - sandstones contain characteristically small amounts of s element, not exceeding 1.2 micrograms per gram.

7. Granitoids of the tin-tungsten formations are characterized by preciable variations in their molybdenum: from 0.7 (Aldakachan, yka) to 3.8 (Durulgui porphyry-like granite) micrograms per gram.

Ordinary concentrations of molybdenum are observed in the intru- ve complexes of the polymetallic zone.

8. The results here obtained testify to the effect that feldspars of e intrusive formations here examined are characterized by the west amounts of molybdenum. This element is present in feldspars concentrations near the limit of its spectrographic detection (0.5 crograms per gram).

Anomalous (somewhat higher) concentrations of molybdenum are ted, as a rule, in feldspars of rocks showing effects of hydrothermal erations (tuffs of the Bugdaya quartz porphyries, the Shakhtama anite-porphyries). Characteristically, feldspars of the intrusive mplexes of the polymetallic metallogenic zone show no anomalous ncentrations of molybdenum.

Analogous patterns are observed for biotites and hornblendes. ere is no accumulation of molybdenum in these minerals. Their erage molybdenum content is 0.5 to 1 micrograms per gram and is rely as high as 2 to 4 micrograms per gram.

9. Sphenes are remarkable for their high content of molybdenum. is element is found in every one of the samples of sphene here in- stigated. Molybdenum could be detected in only one sample of hene from the syenite-diorite Akatui Intrusive Complex with which ead mineralization is associated. Concentrations of this element ry within a wide range: 34 to 400 micrograms per gram. Sphenes m molybdenum-bearing intrusive complexes are characteristically her in molybdenum than sphenes from intrusive rocks from the tricts where there are indications of a polymetallic mineralization.

10. There is appreciable variation in the molybdenum content of four samples of ilmenite from traces to 328 micrograms per

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udnyi Uzel” (“ore knot”) in the sense of the focus or the core of the min- alized area. VPS gram. Significantly larger concentrations of molybdenum are noted in ilmenite from the tin-tungsten granitoids (Aldakachan, Belukha) than in ilmenites from granitoids of the polymetallic complex (Kadaya).

Molybdenum is present in magnetites, as a rule. Its average concentrations in magnetite vary within the range of 1 to 2 micrograms per gram and may be as high as 10 micrograms per gram only in rare cases.

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DISTRIBUTION OF RARE EARTHS IN ROCK-FORMING AND ACCESSORY MINERALS OF CERTAIN GRANITES

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Abstract

ı the granite from the Kirovograd district (Ukraine) the distribution of rare ıs in the granite itself and in separate minerals has been determined. The ı part of the rare earths is contained in monazite. Rare earths are also ent in rock-forming minerals (biotite, microcline). In calcium-containing rals (apatite, garnet) a higher content of rare earths has been noted. The part of rare earths precipitate in the final crystallization state of the melt a decrease of the alkali concentration.

Distribution of the rare earth elements in rock-forming and acces- minerals is one of the major problems in geochemistry of these ıents.

t was shown by E. E. Vainshtein, A. I. Tugarinov, and N. V. anskaya [1] that amounts and proportions of the rare earths in rocks practically constant, despite differences in the age of intrusions and ite variations in the kind of rare earth minerals in the Ukrainian itoids. These authors also remarked that a part of the rare earths efly the yttrium group) is bound with certain other minerals, al- gh the bulk of the rare earths in the granitoids is in monazites or llanites of the intrusive rock.

here was an attempt, for that reason, to examine the distribution of rare earths in every mineral of one of the Ukrainian granite types, s to strike the general balance of their distribution.

ccording to these authors [1], the total rare earths constitute 7% of the Kirovograd granite (sample 1052/5), while there is not e than 0.003% monazite in the same granite, as shown by thin sec- s. Consequently, only 10% of the total rare earths may be accounted y the presence of monazite.

he same Kirovograd granite (sample 1052/5) from the vicinity of kleya River was used in further studies of the balance and the dis- ıtion of the rare earths in granites.

order to strike a general balance for the rare earths in granites, s essential to ascertain the exact quantitative mineralogic compo- n of the granite and to determine proportions of the rare earths in y one of the single-mineral fractions of the rock.

The quantitative mineralogic estimates were made in large thin sections under a binocular stereoscopic microscope MBS-2 with supplementary accessories in the lens and with the two-polaroid illuminator suggested by L. V. Dmitriev [2]. A measuring grid, with the side of the square equal to 7 mm, was imposed on the whole of the thin section. The amounts of rock-forming minerals were estimated at the Ocular 8, Objective 2 magnifications; Ocular 8, Objective 4 were used for the accessory minerals. A standard ocular grid with 225 squares was used in making the estimates. The area of this grid was 1.5 by 1.5 cm.

Single-mineral fractions were hand-picked under the binocular microscope from a panned sample derived by elutriation of the crushed granite (wt. of sample ca. 15 kg). The light-weight fraction produced by the crushing of granite was isolated from the 0.15 mm material by means of bromoform followed by a prolonged electromagnetic purification.

The relatively low sensitivity of the X-ray spectrographic method caused major difficulties in the determination of amounts and composition of the rare earths, and it was found necessary to undertake an appreciable chemical up-grading of every one of the single-mineral fractions. Aliquots of the single-mineral fractions ranging in weight from 30 grams to 1 gram (for light-weight minerals and for apatite respectively) were used for the up-grading. The chemical up-grading was done by the procedure suggested by E. K. Golbraikh. The minerals and the rare earth concentrates were analyzed by the X-ray spectrographic method [3].

The mean arithmetical error of the analysis for individual rare earth constituents of the samples was about 5%. The maximum total error in determinations of the sum of the rare earths by the procedure here employed may be of the order of magnitude of 20%.

The Kirovograd granite represented by sample 1052/5 from the vicinity of Sugakleya River is a gray porphyry-like biotite granite entirely homogeneous in all of the 6 open quarries situated about 6 km each from the other.

Macroscopically the granite is a gray porphyry-like rock with large crystals of gray microcline from 2 or 3 to 5 cm in length. Fine crystals of cherry-red garnet are disseminated throughout the rock.

Microscopic studies indicate the following mineralogic composition of the granite:

The accessory minerals are apatite, monazite, zircon (rarely), and an ore mineral; the dark minerals are biotite and a small amount of chlorite (after biotite); the colorless minerals are plagioclase, microcline, quartz, and muscovite. In addition to these, the rock contains small amounts of almost colorless garnet. We are not reporting here a detailed mineralogic composition of the granite because this was not the objective of our study. A complete microscopic description of Kirovograd granites, including the granite from the vicinity of Sugakleya River, was published by Yu. I. Polovinkina [4].

The order of crystallization of minerals in our granite is a very
fficult problem, inasmuch as the entire problem of the origin of Pre-
mbrian granites is still controversial.

B. Ya. Khoreva [5] believes that there should be no exclusion of the
ssibility that some of the Ukrainian granites could have been formed
etasomatically.

As an example, she describes the granites of the Saksagan River
d, specifically, the gray porphyroid granites of the Kirovograd Mag-
atic Complex which are the granites of the Savro Open Cut. She
gards all of the Saksagan granites as typical migmatites. We are
clined to agree with B. Ya. Khoreva, with regard to the possibility
at some of the granites in question may have been formed meta-
matically.

However, there can be no doubt as to the magmatic origin of the
rovograd granites. Judging by the presence of garnet, by the some-
at irregular distribution of the minerals in the vicinity of the roof
the intrusive body, we may only presume the partially hybrid origin
the granitoid in question.

The following sequence of crystallization of minerals is definable in
e granite we investigated, the structure of which is definitely por-
yroid:

1. The earliest deposited species are represented by plagioclase
d biotite of the 1st generation, observed in the cores of the dissemi-
ted microcline. Plagioclase I is present as intensively seriticized
ains corroded partially by microcline. Biotite I is very scarce and
present as small scales without any inclusions of radioactive min-
als, as a rule.

2. The bulk of the rock (up to 50%) consists of phenocrysts of
crocline I and, to a lesser extent, of plagioclase II which is not as
ensely seriticized as plagioclase I. Some individual phenocrysts of
gioclase II may be up to 2 or 3 cm in diameter.

3. The groundmass of the rock consists of quartz I, biotite II,
gioclase III, microcline II, and garnet; the first two minerals are
finitely predominant. Biotite is conspicuous among the earliest
nerals of which the bulk of the rock is composed. In places, biotite
ms the characteristic zones at the contacts between quartz and the
enocrysts of microcline which is corroded by biotite. Characteris-
ally, the bulk of the accessory minerals (apatite, monazite) is asso-
ted especially with this biotite II; the accessory minerals are seen
th as they surround the particles of biotite and included the biotite,
ng its cleavage planes. The formation of garnet takes place also
ring this stage.

Thus a very important conclusion is drawn from the microscopic
dence here presented:

The bulk of the rare earths is contained either in the rare earth
nerals (monazite) or in the rare earth-admissive minerals (apatite,
net) and this bulk was separated from the hypothetical magmatic
ution and was passed into the solid phase after the crystallization

of the principal aluminosilicates and during the stage after the last of the alkali minerals were formed (biotite). In such manner we are enabled further to conclude that the rare earths remaining in the residual melt were probably closely bound to the alkalies that were accumulated therein.

The next urgent problem is to ascertain the balance in the distribution of the rare earths among the minerals and, first of all, to ascertain their amounts tied in the accessory minerals.

Determination of the amounts of monazite, as the most diagnostic rare earth mineral, in the rock was done by separate counts of the grains of this mineral, by their abundance and size. The results of these counts in two thin sections are shown diagrammatically in

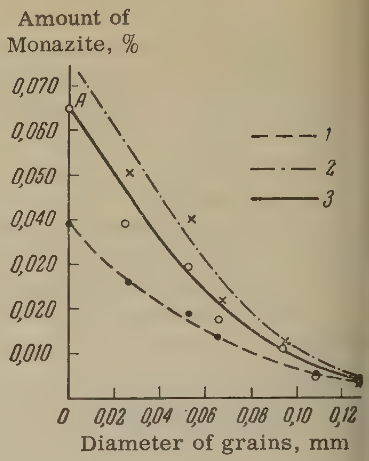

Fig. 1. The content of monazite in granite: 1—in thin section 1052/5 - I; 2—in thin section 1052/5 - II; 3—average of two thin sections.

Table 1. Monazite Content of Rock, as Monazite Grains of Different Size

Size of Monazite Grains, as fractions of the area of 1 square of the standard grid	Diameter of Monazite Grains, mm.	Number of Monazite Grains of the Measured Size Thin Section No.		Number of Squares whose Area is occupied by Monazite of the Measured size Thin Section No.		Amounts of Monazite in Grain of the Measured Size, % by weight Thin Section No.		
		1052/5-I	1052/5-II	1052/5-I	1052/5-II	1052/5-I	1052/5-II	Averag of Tw Section
$\frac{1}{200}$	-	21	1	0.105	0.005	0.00034	0.00002	0.0001
$\frac{1}{100}$	0.027	134	79	1.340	0.790	0.00435	0.00252	0.0034
$\frac{1}{50}$	-	45	120	0.900	2.400	0.00292	0.00766	0.0052
$\frac{1}{25}$	0.054	33	149	1.320	5.960	0.00429	0.01901	0.0116
$\frac{1}{20}$	-	3	-	0.150	-	0.00049	-	0.0002
$\frac{1}{16}$	0.067	11	34	0.660	2.040	0.00214	0.00651	0.0043
$\frac{1}{12}$	-	4	8	0.332	0.664	0.00108	0.00219	0.0016
$\frac{1}{10}$	-	-	1	-	0.100	-	0.00032	0.0001
$\frac{1}{8}$	0.095	10	12	1.250	1.500	0.00406	0.00479	0.0044
$\frac{1}{6}$	-	3	6	0.500	1.000	0.00162	0.00319	0.0024
$\frac{1}{5}$	0.11	2	1	0.400	0.200	0.00130	0.00064	0.0009
$\frac{1}{4}$	0.13	2	-	0.500	-	0.00162	-	0.0008
$\frac{1}{3}$	-	2	1	0.670	0.330	0.00218	0.00105	0.0016
$\frac{2}{3}$	-	-	1	-	0.670	-	0.00214	0.0010
Sum	-	-	-	8.000	15.658	0.02639	0.05004	0.0382

igure 1 and recorded in Table 1. The results of the counts of all inerals, in the two thin sections separately are reported in Table 2, ogether with their averages and with additional data on the kind and mounts of the rare earths in the rock-forming and in the accessory inerals.

As is evident from the diagram, the amount of monazite increases egularly as the smaller grains are included progressively in the ount.

In such manner the upper limit of the concentration of monazite, ncluding the finest grains smaller than 0.02 mm in diameter, should e in the vicinity of 0.06%, according to the theoretical curves (point A''), i.e. should correspond to the upper limit established by the irect chemical determination of the rare earths in the rock. In such ase, practically all of the rare earths contained by the rock should e associated only with monazite. As we shall presently see, however, his assumption is contradicted, for example, by the fact that the rare arths present in the other rock-forming and accessory minerals have somewhat different composition.

It is perfectly clear theoretically that, below a certain hypothetical ize of the monazite grains, at a certain stage of the dispersion, the ineral cannot exist independently, as it can scarcely attain the size f even one single molecule, and that the constituents of monazite must nter the structures of some host mineral. Particles of monazite maller than 0.02 mm could never be seen under the microscope, for ll practical purposes, despite the sizeable halo of the radioactive lteration which would have been their microscopically diagnostic ndication.

No monazite nor apatite was detected in the feldspar, with the exeption of a few isolated grains whose origin appears to be vague, nder the microscope, and possibly related to the penetration of the onazitic substance into the feldspar after the latter was formed.

We were obliged, for that reason, to limit our investigation by the onclusion (Table 2) that at least ca. 60% of the rare earths in the ranite is definitely bound with the monazite, while the rare earths in he rock-forming minerals are present either in the dispersed exremely small monazite particles, smaller than 0.02 mm in diameter, r in the crystal structures of the rock-forming minerals.

From the data of the summary Table 2, as well as from the decription of the granites, it follows, within the limits of experimental rror (20%) that the distribution of the rare earths among the minerls of which the granite is composed is now made clear and that the um-total of the rare earths in the individual minerals is roughly the ame as the total rare earths in the sample of the whole rock.

Characteristically, an appreciable portion of the rare earths, 9.23%, not counting the monazite, is found in the quartz-feldspar action. Microscopic studies show convincingly, nevertheless, that nly two monazite grains are seen to be included in the coarse grains f feldspars, in the large thin section, whereas the bulk of the

Table 2. Distribution of Individual Rare Earths in Minerals of Granite

Mineral	Content of Minerals				% Rare Earths	Amount of Rare Earths in 1 gram of rock	% Rare Earths in the given Mineral, as of total Rare Earths in the Minerals
	% by Volume Thin Section No.		Average of 2 Sections	% by weight Average of 2 Sections			
	1052/5-I	1052/5-II					
Feldspars	64.50	93.71*	94.77	94.77	0.01	0.0095	29.23
Quartz	31.34						
Biotite	2.71	5.83	4.27	4.82	0.06	0.0029	8.92
Chlorite	0.42	0.01	0.22	0.57	0.06***	0.0002	0.62
Garnet	0.92	0.22	0.57	0.80	0.03	0.0002	0.62
Apatite	0.033	0.19	0.11	0.13	0.5	0.0007	2.15
Monazite	0.013	0.025	0.019	0.038	50.0	0.019	58.46
Zircon	not dtd.	0.004	0.004**	0.007	not dtd.	-	-
Opaque minerals	0.053	not dtd.	0.053**	0.103	not dtd.	-	-
Sum	99.99	99.89	100.17	100.92	-	0.0325	87.84
Average Sample	-	-	-	-	-	0.037	100.00

*Not differentiated in the analysis.

**The figure is based on measurements in one thin section only.

***The rare earths were not determined; the figure for biotite is used.

monazite is associated with biotite. Judging by the sufficiently close resemblance between the composition of the rare earths in the monazite and in the quartz-feldspar fractions of the rock and taking into account the previously stated considerations regarding the possibility of the dispersion of monazite as such, we cannot exclude the possibility that this particular fraction of the rare earths may include also the disseminated monazite whose grains are not recognizable because of the limitations of the resolving power of the microscope. However, inasmuch as monazite was practically never detectable in the feldspar phenocrysts, the possible alternative involving the entry of the rare earths into the crystal structures of plagioclase and microcline needs not be dismissed from our consideration, in view of its certain tenuous support by the somewhat too-low amounts of lanthanum contained therein.

There also is another relationship, characteristic of the granite in question, strikingly conspicuous at a glance at Table 2: the more biotite in the rock—the more accessory minerals apatite and monazite.

Characteristically, monazite, apatite, garnet, and biotite also capture a part of the rare earths, however insignificant, of a clearly different composition, in their crystallization which is practically contemporaneous with the crystallization of monazite. Thus, for example, the yttrium earths are predominant in the garnet, whereas there is a marked increase of Ce and La in the biotite, an increase not only by comparison with the average composition of the rare earths in the rock but also in comparison with their composition in the monazite.

Thus our results fully sustain the selective capacity of calcium minerals to capture chiefly the yttrium rare earths, which was previously reported by Khaberlandt [6] on the basis of the data obtained by spectrographic analysis.

Table 2. (cont.)

Mineral	La	Ce	Pr	Nd	Sm	Gd	Dy	Tb	Er	Ho	Y	Yb	Lu
Feldspars Quartz	6.7	14.6	1.4	5.6	1.0	-	-	-	-	-	-	-	-
Biotite Chlorite	2.07	4.05	0.51	2.0	0.43	0.32	0.18	-	-	-	-	-	-
Garnet	-	0.035	-	0.026	0.011	0.067	0.18	-	0.13	0.033	0.066	0.063	0.01
Apalite	0.11	0.40	0.079	0.36	0.14	0.18	0.16	0.046	0.057	0.039	0.575	-	-
Monazite	15.5	26.9	2.6	10.3	1.8	1.4	-	-	-	-	-	-	-
Zircon	-	-	-	-	-	-	-	-	-	-	-	-	-
Opaque minerals	-	-	-	-	-	-	-	-	-	-	-	-	-
Sum	24.4	46.0	4.6	18.26	3.38	2.0	0.52	0.046	0.187	0.072	0.641	0.063	0.01
Average Sample	24.6	47.2	4.9	19.7	3.54	-	-	-	-	-	-	-	-

CONCLUSIONS

1. The bulk of the rare earths in a granite of the monazite type is associated with monazite.
2. In granites, the rare earths may also be present both in the accessory and in the rock-forming minerals in which their concentrations may be up to 0.06% (as in biotite).
3. The rare earths accumulated in calcium minerals (apatite, garnet) show a higher $\frac{\Sigma Y}{\Sigma Ce}$ ratio than the rare earths in the aluminosilicates (biotite, microcline).
4. The bulk of the rare earths in the monazite-bearing granite here studied was extracted from the solution-melt not during the initial stages of the magmatic crystallization but only after the crystallization of the bulk of the aluminosilicates and after the marked decrease of the alkali concentration in the residual melt.

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GEOCHEMISTRY OF SCANDIUM IN THE SUPERGENE ZONE

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Abstract

The leaching of scandium from scandium-bearing minerals in the oxidation
ne, observed by the author, is described. Scandium is leached especially in-
nsively from wolframite in the oxidation zone in steppe regions as well as from
lanite in the outcrops on the surface. The importance of studying this phenom-
on is to ascertain the manner of scandium entrance into the wolframite and
lanite lattice as well as to learn to prospect for new scandium deposits.

From mineralogic studies of wolframite, allanite, and other types of
re-metal deposits within the supergene zone, one of their major
aracteristics becomes apparent in all: the leaching of scandium, to
e point of its complete disappearance from a number of scandium-
aring minerals, such as wolframite, allanite, and others. There can
no doubt at the same time that scandium content of some other min-
als, like cassiterite, remains unaffected in the oxidized zone and is
e same as it was in the primary zone.

Quantitative determinations of scandium reported in this article
ere made at the Giredmet* Spectrographic Laboratory.

Scandium in wolframites was determined by the quantitative spectro-
aphic procedure developed by A. K. Rusanov and S. M. Solodovnikov
]. This procedure amounts to a direct determination of scandium
ith the aid of the internal lanthanum standard and of the appropriate
libration. Reliability of this method, for wolframite, is ± 8%.
andium was determined in allanites by the density of its lines, as
ainst the graduated standard graph. This spectrographic procedure
reliable within ± 20 to 30%.

SCANDIUM-BEARING WOLFRAMITES IN OXIDIZED ZONE

Detailed studies of wolframite deposits had shown the wolframites
om veins outcropping at the surface and in the oxidized zone below
e thoroughly altered, not only in the steppe environments but also in
untainous districts, according to more recent findings.

The erosion process, and the resulting exposure of fresh levels of
deposit, are very slow in steppe districts, while the "heads" of

osudarstvennyi Institut Redkihi Malyh Metallov. VPS the exposed veins are subjected to a prolonged and intensive alteration. In such environments (Central Kazakhstan and other steppe districts), there is a formation of the severely weathered, so-called "baked" wolframite, which was described in detail by F. V. Chukhrov [2]. The alteration leads, under such conditions, to a complete destruction of the wolframite crystal lattice. The alteration consists of a complete conversion of the ferrous iron into ferric, whereas there is very little change in the MnO content of the mineral.

As a convincing example of this process, we may cite here the analyses of wolframites from a deposit in Central Kazakhstan, according to F. V. Chukhrov (Table 1).

Table 1. Iron Content of Wolframite as Influenced by Weathering

Constituent	Fresh Wolframite Per Cent	Weathered Wolframite Per Cent
MnO	11.40	8.90
CaO	-	0.28
MgO	-	0.14
FeO	11.86	-
Fe_2O_3	-	32.90
Al_2O_3	-	0.75
WO_3	74.98	46.96
H_2O+	-	8.25
SiO_2	1.42	1.92
	99.66	100.10

These analyses show that ferrous oxide is entirely absent in the altered wolframite, whereas ferric oxide is present—and in very large quantities.

In mountainous regions at intermediate latitudes, where ore bodies are subjected to a very active erosion, there may be no appreciable changes in wolframites in many cases. There are also districts where the alteration of wolframites in the oxidized zone is analogous to that in the "baked" wolframites in Central Kazakhstan. The Oigaing Deposit, situated in one of the mountainous districts of Kirgizia, is a convincing example of such alteration. According to A. S. Povarenykh [3], the Oigaing wolframites are strongly altered in the oxidized zone of this deposit (Table 2).

Thus also in this case FeO decreases from 16.13% in fresh wolframite to 1.07% in severely altered wolframite, whereas Fe_2O_3 increases from 1.83 to 60.09%; i.e., the result is the same as in the wolframites from the Kazakhstan steppe (see Table 1).

As one may see from Table 2, the alteration of wolframite leads to a marked decrease in its specific gravity and hardness.

Wolframites undergo a severe alteration in tropical climatic environments, where the supergene zone is conspicuously expressed at rare metal deposits, not only in lowlands but also in high mountainous terrains. According to Van Bemmelen [5], depths of the oxidized zone in tin-tungsten deposits of Indonesia may attain several hundred meters. Wolframite is very intensely altered also in Bolivian deposits, despite their being in the Andes, at high altitudes above the sea level [4].

Table 2. Supergene Alteration of Oigaing Wolframites (according to A.S. Povarenykh)

Constituent	Fresh Wolframite Per Cent	Early Stage of Alteration Per Cent	Terminal Stage of Alteration Per Cent
WO_3	73.04	51.36	17.73
FeO	16.13	8.85	1.07
MnO	5.23	5.11	2.13
CaO	1.93	2.40	4.21
MgO	0.28	0.38	0.74
F_2O_3	1.83	18.82	60.09
SiO_2	0.42	1.58	1.46
H_2O	0.27	9.91	12.11
F	trace	0.70	1.02
Sum	99.13	99.11	100.56
Correction, F_2=0	-	0.29	0.42
Corrected sum	99.13	98.82	100.14
Sp. gravity	6.77	4.55	3.96
Hardness	5.5	3.5	1.5 to 2

But what happens the scandium in course of such ensive alterations wolframite? nong the first de- sits studied by the thor in this con- ction was a small -tungsten deposit, Maikul in Pri- lkhashe. The de- sit consists of artz veins with lframite, cassi- rite, feldspar, paz, and muscovite. e scandium content fresh wolframite nges from 0.5 to 3%, whereas in the verely altered, the -called baked wolf- mite, there are only traces of scandium. It is noteworthy also that decrease of scandium in wolframite proceeds parallel to the de- ease of ferrous iron and to the increase of ferric iron.

The intensive and almost total leaching of scandium out of wolfra- tes in the supergene zone is observed at all scandium-bearing posits in steppe localities. The alterations of wolframite are less ensive in montane terrains at intermediate latitudes, where it de- nds directly on fracturing of the veins.

Alongside severely altered crystals of wolframite within the dense artz, in the same veins, there are also practically fresh crystals of mineral. Nevertheless, in several cases, analogous to the Oigaing ready described, there is an intensive alteration of wolframite crys- s, accompanied by a marked decrease in FeO and an increase in $_2O_3$. The scandium content decreases appreciably in such cases. e alterations of wolframite in deposits in tropical countries are en more severe.

Thus wolframite is intensively altered, and scandium, if present iginally, is almost completely leached out in the supergene zone of ny mining districts. We must be very cautious, therefore, in our praisal of the possibilities of scandium in wolframites, on the basis surficial outcrops or the showings in trenches or in shallow bore- es. We should consider also the fact that scandium in wolframites m placers as a rule, is far lower than in wolframites from the mary ore zones of the original deposits, in one and the same ndium district.

The parallelism in the decrease of both scandium and ferrous iron accompanying the alteration of wolframite suggests, in all probability, that scandium replaces ferrous iron isomorphously in this particular case.

SCANDIUM-BEARING ALLANITES IN OXIDIZED ZONE

The decreases of scandium in the supergene zone, in a manner analogous to the relationship established for wolframites, are observed also in the case of allanites. Alterations of this kind are very characteristic for the scandium-bearing allanites of Karelia. At the deposits of Alakurtti, Panfilova Varaka, and Chalovskoe, there is an intensive alteration of allanites in the walls of open mining workings, in trenches, and in dumps, to the point of their conversion into their loose and brown variety.

Table 3. Scandium in Fresh and in Altered Allanites of Karelia

Deposit	Pitch-black Allanites Per Cent Sc	Brown Allanite Per Cent Sc
Alakurtti Vein No. 1	0.100	0.030
Panfilova Varaka	0.070	0.016
Chalovskoe	0.050	0.015

The alteration of allanite is especially conspicuous at the Alakurtti. Allanites in the walls of trenches, dug only 3 to 4 years ago, although remaining pitch-black in the axial part of the crystals, are now brown at the periphery, with accompanying marked changes in the index of refraction of the mineral. The scandium content of the central part of the crystals is up to 0.1%, but is only 0.02 to 0.03% in the altered part of the same crystals. About the same picture may be seen in the case of other scandium-bearing allanites of Karelia (Table 3).

The depth of the oxidized zone of pegmatitic veins is shallow, in relation to the characteristics of the vein structures: sparsely disseminated allanite in large single crystals of feldspar. Consequently, the leaching of scandium from the allanites is traceable only to shallow depths in such environments. At the same time the intensity and the ubiquitousness of the process attracts our attention.

OTHER SCANDIUM-BEARING MINERALS IN THE SUPERGENE ZONE, AND CERTAIN CONCLUSIONS

The scandium content of cassiterite in the oxidized zone remains entirely unchanged, as against the primary zone. This appears to be due to the stability of cassiterite in the supergene zone. The behavior of rare scandium-bearing minerals, such as thortveitite, khlopinite, wiikite, and samarskite in the oxidized zone has not been studied by

one. It is most probable that a leaching of scandium in the oxidized
e will prove to be characteristic also for these minerals. One can-
exclude the possibility that variations in the amounts of scandium
de in thortveitites, from 42 to 35%, may be explained by differences
he state of oxidation of scandium.

It is probable that some leaching of scandium takes place also in the
e of amphiboles, pyroxenes, and other dark constituents of basic
ks. Consequently, in order to arrive at geochemically reliable con-
sions, including those referring to the average amounts of scandium
rocks, we must select dense and unaltered rocks and minerals for
analysis.

The intensive leaching of scandium out of scandium-bearing miner-
, in the supergene zone, leads us to the idea of its possible accumu-
ion in the oxidized zone. It should be desirable, in this connection,
check the scandium content of different ochres accumulating in the
ergene zone at different polymetallic deposits. First of all, we
ht to check the bismuth ochres, so common in the oxidized zone of
ymetallic deposits.

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MIGRATION OF ELEMENTS IN UNDERGROUND AND SURFACE WATERS OF THE UPPER-KAIRAKTY DISTRICT, CENTRAL KAZAKHSTAN

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Abstract

The regularities of distribution in the migration of metals in underground and surface waters of the Verkhnekairaktinsk district in the Central Kazakhstan are considered, and the problems of the formation of hydrochemical anomalies and of water dissemination haloes of ore elements have been considered. Methods of analyzing the hydrochemical anomalies in prospecting for ore deposits in an arid climate are demonstrated.

The district here to be discussed is situated in the "melkosopochnik"* of Central Kazakhstan, in the basin of the Kairakty, Bes-Baldak, and Karamys Rivers. The relief is dissected and the climate is continental, but relatively humid. The annual atmospheric precipitation is 235 to 250 mm and may be as high as 327 mm.

The district is underlain by highly metamorphosed Silurian sandy-clayey shales and by Devonian and Carboniferous effusive sedimentary rocks. Intruding the effusive sedimentary beds and the metamorphosed shales are small bodies of quartz-porphyries, felsite-porphyries, and granite-porphyries. Faulting is common in the district. Rocks in direct proximity to such disturbances are compacted and brecciated. Within the weathered zone, 80 to 100 meters thick, the rocks are cut by a dense network of fine fissures wedging-out rapidly in depth. The eluvial-diluvial materials (with rubble of the underlying rocks) are relatively thin: up to 1 meter on the water-divides, increasing to 3 to 5 meters at the base of the slopes. The stream valleys are composed of heterogeneous loam and sandy-clayey alluvial sediments. The rocks composing the district include some disseminated ore minerals which constitute a background for a series of ore deposits, chiefly of the rare metals, but also of manganese and of lead-copper-barite.

The tungsten deposit at Upper Kairakty, investigated geologically and hydrologically in detail, occurs in metamorphosed Silurian shales chists). The deposit is situated on the Kairakty-BesBaldak water- vide, on the Ak-Shoko sopka* range. The ore is found in a network fine fissures filled by quartz in which the ore minerals are embed- d: scheelite, wolframite, molybdenite, and others (a stockwork). e molybdenum content is poor and its distribution in the rocks is regular. The rocks and the ores are exposed over an appreciable rt of the mineralized area. The oxidized zone is only 20 to 80 eters thick, due to the high density and of the fine schistosity of the cks.

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*"Melkosopocknik" is the terrain formed by irregularly spaced rounded low hills or chains of hills, including isolated broad-based sharp-peaked hills, separated by broad and mature stream valleys. There is no English equivalent of this geomorphologic term. VPS

Both hard rocks and loose materials (the latter are chiefly in the ver valleys and in gulleys) are contacted by waters very irregularly. e metamorphosed shales (schists) have very little contact with the ters. The discharge of springs issuing from these rocks does not ceed a few tenths of one liter per second. The water-bearing capac- y of brecciated rocks (Dzhaksy-Tagaly and Monatai Mountains) is finitely higher. Some of their springs have a discharge of 1 to 2 ers per second.

The low permeability of the metamorphic and effusive-sedimentary cks occupying extensive areas in the district, and the dissected re- ef, are conducive to a short-term and active water exchange, as the filtrating waters travel but short distances through the rocks and e discharged very rapidly. These special features of the hydrologic vironment of the district result in the development of fresh and ultra- esh waters, low in sulfates (0 to 85 mg/liter) and low in total dis- lved salts (0.1 to 0.5 grams/liter). As shown in Figures 1 and 2, ey are chiefly calcium bicarbonate waters; sodium and magnesium carbonate waters are more rare and are associated particularly th the mineralized rocks, along with some occasional sodium and lcium sulfate waters, acid, neutral, and weakly alkaline (pH 5.8 to 8). Waters of the unconsolidated eluvial-diluvial materials resemble ters of the hard rocks in their composition, as a rule. Surface ters and waters of alluvial sediments, whose development and com- sition are influenced by evaporation, are highly mineralized saline, ntaining 1 to 3 grams per liter of total salts—chiefly sodium sulfate d chloride.

Waters of the same composition are found also in loose formations different origins, wherever the loose materials are sealed off by e underlying Tertiary dense clays (for example, in Severnyi Gully, igure 1).

The underground waters in the schists at Upper Kairakty are zonal their chemical composition (Figure 1). On the Ak-Shoko Sopka, ere the rocks are most highly mineralized and hydrothermally tered, the waters are of the magnesium bicarbonate type. Farther ay, downslope, sodium takes the place of magnesium in the bicar- nate waters in the schists, whereas in the trough of the southwestern

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Sopka'' is a low isolated hill in Siberia and Central Asia, a volcano in amachatka, a mud volcano in Caucasus. VPS

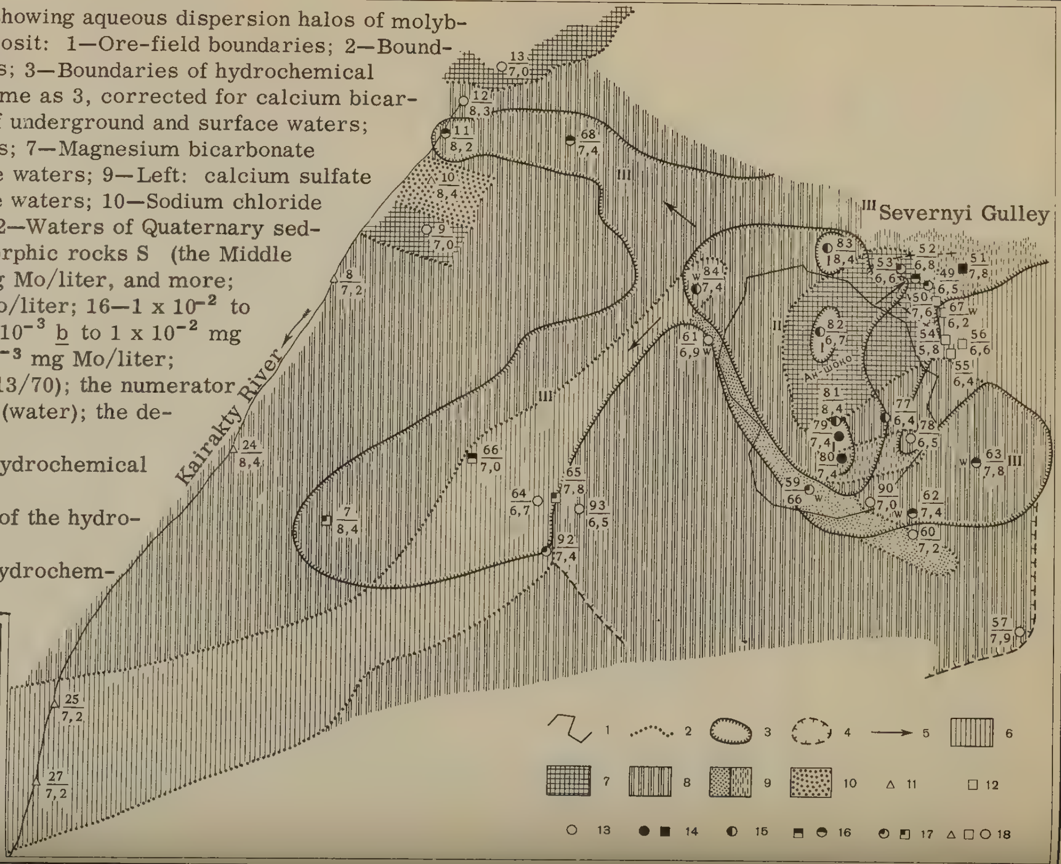


Fig. 1. Hydrochemical Map showing aqueous dispersion halos of molybdenum at upper Kairakty deposit: 1—Ore-field boundaries; 2—Boundaries of hydrochemical fields; 3—Boundaries of hydrochemical molybdenum anomalies; 4—Same as 3, corrected for calcium bicarbonate; 5—Direction of flow of underground and surface waters; 6—Calcium bicarbonate waters; 7—Magnesium bicarbonate waters; 8—Sodium bicarbonate waters; 9—Left: calcium sulfate waters; right: sodium sulfate waters; 10—Sodium chloride waters; 11—Surface waters; 12—Waters of Quaternary sediments; 13—Waters of metamorphic rocks S (the Middle Silurian, VPS); 14—8×10^{-2} mg Mo/liter, and more; 15—2×10^{-2} to 2×10^{-2} mg Mo/liter; 16—1×10^{-2} to 2×10^{-2} mg Mo/liter; 17—5×10^{-3} b to 1×10^{-2} mg Mo/liter; 18—Less than 5×10^{-3} mg Mo/liter; "W" tungsten present (e.g. 13/70); the numerator is the No. of the sampling site (water); the denominator is pH of the sample.

I. The inner zone of the hydrochemical anomaly.

II. The intermediate zone of the hydrochemical anomaly.

III. The outer zone of the hydrochemical anomaly.

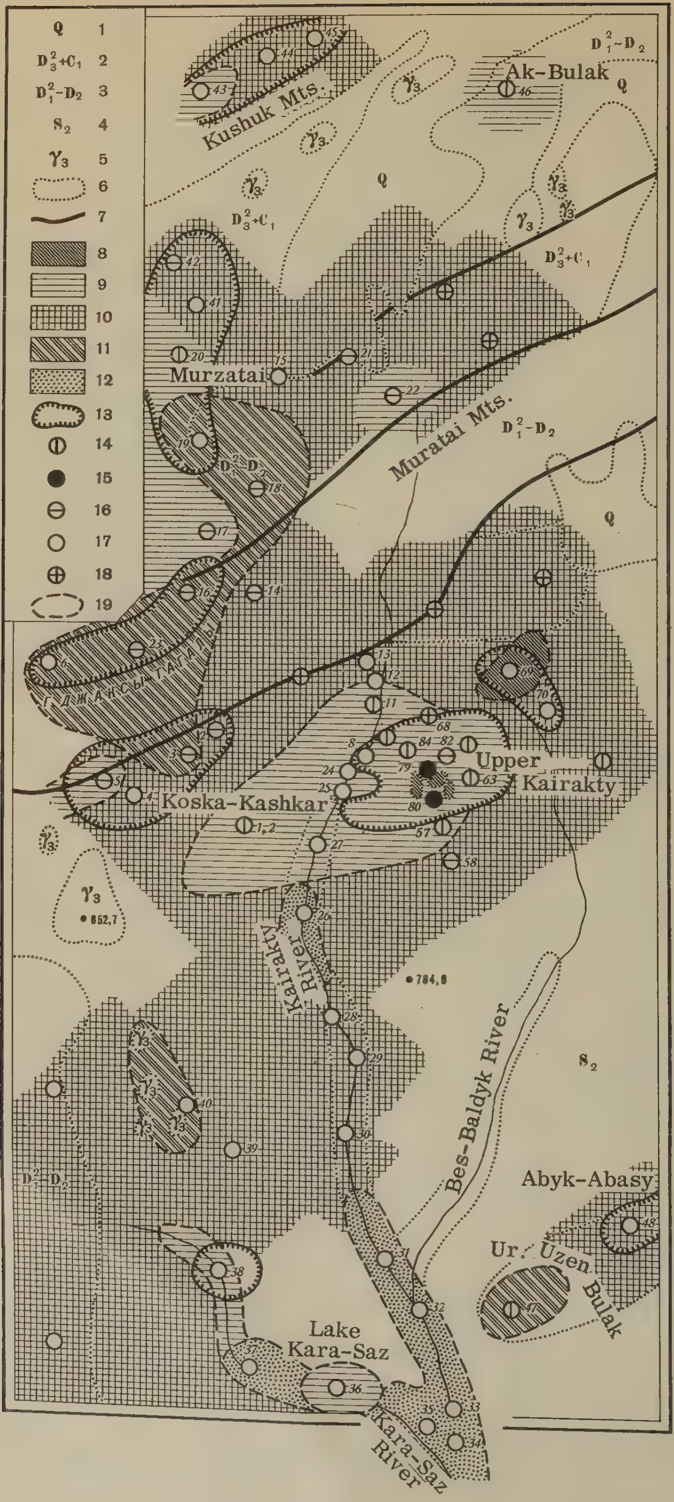
Table 1. Occurrence of Metals in Natural Waters of the District and of the Upper Kairakty Deposit (in per cent)

Test Materials		Mo	Cu	Pb	W	Ni	Ag	V	Ga	Y	La	Sn	As	Zr	Mn	Ti	Sr	Ba	Cr	Zn	Remarks
District Waters		55	100	53	16	25	26	33	4.3	11	11	3	1.4	52	98	100	98	37	7.2	4.4	% of total number of samples from the district including the deposit
Waters from ore deposit		26	100	13	12	6	10	11	Not detected	10	10	1.2	Not detected	11	42	100	42	8.4	1.4	Not detected	
		78	100	45	36	19	32	38	Not detected	32	32	4.8	Not detected	38	100	100	100	20	5	Not detected	% of total samples from the deposit

Table 2. Concentration of Metals in Natural Waters of the District and of Upper Kairakty Deposit*

Concentration mg/liter	Mo	Cu	Pb	W	Ni	Ag	V	Ga	Y	La	Sn	As	Zr	Mn	Ti	Sr	Ba	Cr	Zn
District Waters																			
$n.10^{-4}$	2.5	2.0	1.4	-	1.5	1.5	-	-	-	-	1.8	-	-	-	-	-	-	-	-
$n.10^{-3}$	20.2	74.0	35.7	-	16.0	15.5	17.6	4.3	-	-	-	-	2.9	29.0	53.6	2.1	2.0	-	-
$n.10^{-2}$	6.3	24.0	2.8	2.7	1.5	-	4.4	-	-	-	-	1.4	38.1	25.0	39.3	14.5	22.0	2.2	-
$n.10^{-1}$	-	-	-	1.3	-	-	-	-	1.0	1.0	-	-	-	2.0	7.1	33.2	4.0	-	4.4
n.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	-	-	-
Upper Kairakty Waters																			
$n.10^{-4}$	-	10.0	15.0	-	4.7	514.1	9.5	-	4.6	-	-	-	-	5.0	-	-	-	-	-
$n.10^{-3}$	22.4	85.0	30.0	-	14.2	518.9	28.5	-	27.4	4.6	-	-	9.5	85.0	70.0	5.0	-	5.0	-
$n.10^{-2}$	52.3	5.0	-	27.0	-	-	-	-	-	4.6	-	-	28.5	10.0	25.0	75.0	15.0	-	-
$n.10^{-1}$	3.3	-	-	9.0	-	-	-	-	-	18.2	-	-	-	-	5.0	20.0	5.0	-	-
n.10	-	-	-	-	-	-	-	-	-	4.6	-	-	-	-	-	-	-	-	-

*The relative frequency of every concentration is shown as per cent of total samples (Table 1)


Q 1
D$_3^2$+C$_1$ 2
D$_1^2$-D$_2$ 3
S$_2$ 4
γ$_3$ 5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Kushuk Mts.
Ak-Bulak
Murzatai
Muratai Mts.
ДЖАНСЫ-ТАГАЛЫ
Koska-Kashkar
Upper Kairakty
Kairakty River
Bes-Baldyk River
Abyk-Abasy
Ur. Uzen Bulak
Lake Kara-Saz
Kara-Saz River
652,7
784,0
Q
D$_3^2$+C$_1$
D$_1^2$-D$_2$
S$_2$
γ$_3$

pe of the Sopka we find a band of waters in which calcium sulfate is ticeably preponderant among the dissolved constituents (solution of re-precipitated gypsum). In the loose calcareous formations comsing the Main Gully which cuts through the high ground of Ak-Shoko, Ak-Shoko run-off is transformed into waters of the calcium bicarnate type. These waters flow into the Kairakty River Valley, as they t across the hydrochemical zones in the metamorphosed schists. spite the relatively low sulfate of the underground waters (probably result of the slow rates of the oxidation processes), the waters of mineralized zone, here as well as in other districts [2, 3, 5] are stinguished against the regional hydrochemical background by their lfate content. A. A. Brodskii [3] suggested the r SO_4 : r Cl* ratio as criterion for identifying waters of mineralized zones against ters of the regional background. This magnitude is generally great- than 1, for the waters of the mineralized zone of our district. The SO_4 : r Cl ratio is just as high for reservoirs of surface waters and r surface streams far away from the ore bodies, as well as for ters representing the effusive-sedimentary rocks containing disminated sulfides which are chiefly pyritic (Figure 2, Dzhaksy-Tagaly untains, Kushuk). At the same time, the waters representing the es of Ak-Bulak are characterized by the r SO_4 : r Cl < 1.

Underground and surface waters of the district, just characterized the basis of their chemical composition, also carry a complex of etals of different kind (Figure 3). The following metals were dected spectrographically in the dry residues of these waters: Cu, Pb, V, Ni, Co, Cr, Ti, Mn, Sr, La, Zr, Cd, Bi, Ga, Ag, Sb, Li, Zn, Be, W, and, in isolated cases, also As and Sn, as well as Mo, ich was determined by the method of A. A. Reznikov and A. A. chaeva [6].

The metals found in waters representing different lithologicratigraphic complexes reflect the ores of the aquifer rocks. Qualiively, the metallogenic fields (Figure 3) are clearly outlined in the strict by the complex of the metals they contain. As shown in

r'', symbol of ''reacting value'' means that the concentrations are stated as quivalents and not by weight. VPS

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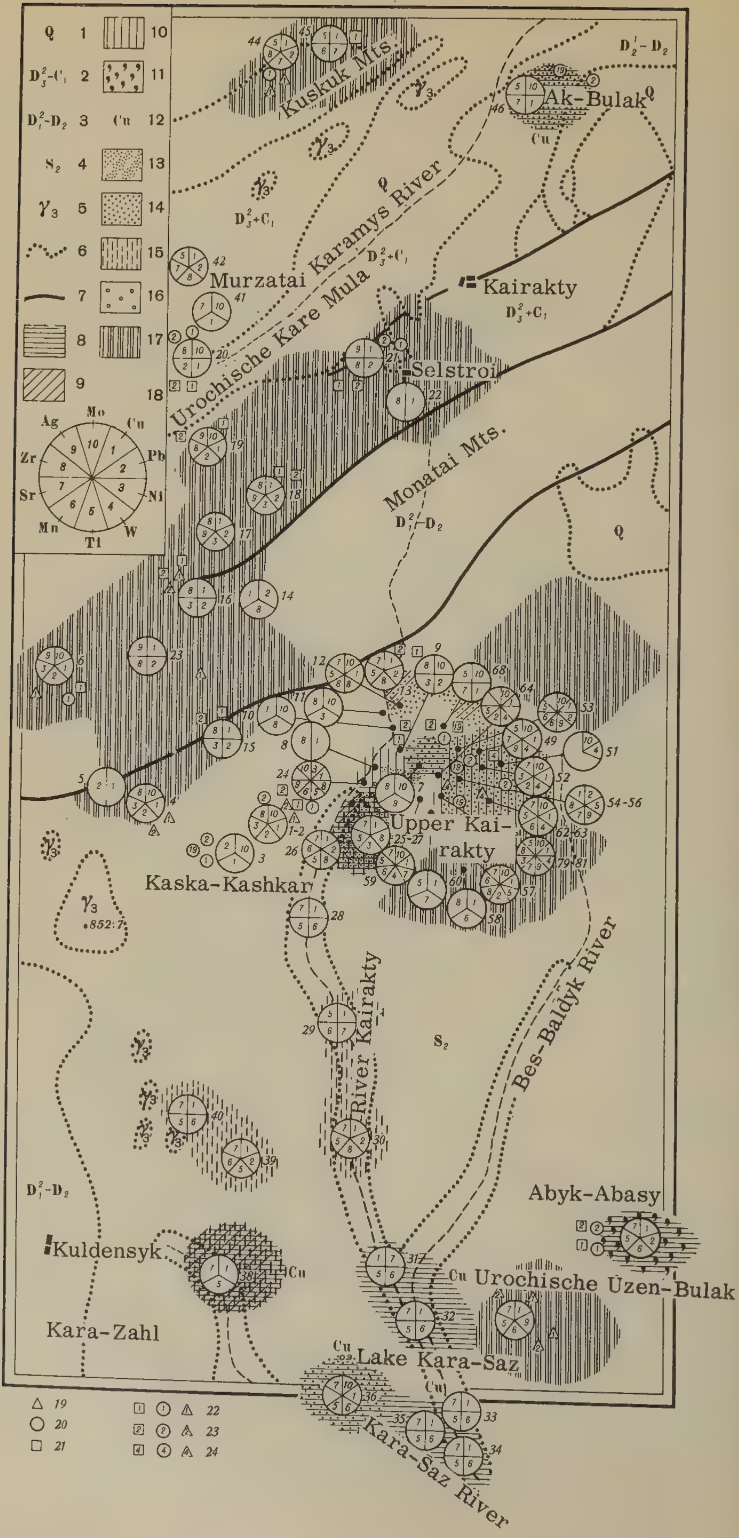
g. 2. Hydrochemical map of the Upper Kairakty district: 1—Alluvial, proluvi- and diluvial sediments; 2—Limestones, sandstones, tuffs, tuffites; 3—Albitophyre ds; 4—Sandstones, shales, effusive basic prophyries and their tuffs; 5—Granite rphyries, intrusive quartz porphyries, felsite porphyries; 6—Boundaries of geoic complexes of rocks; 7—Lines of tectonic disturbances; 8—Sodium and calcium fate waters; 9—Sodium bicarbonate waters; 10—Calcium bicarbonate waters; -Magnesium bicarbonate waters; 12—Sodium chloride waters; 13—The field of eous dispersion with the rSO_4 : rCl ratio higher than 1; 14—Waters containing than 2×10^{-2} mg Mo/liter; 15—Waters containing more than 2×10^{-2} mg Mo/ r; 16—Waters containing more than 5×10^{-3} mg/liter total metals; 17—''Total als'' and molybdenum are not detected; 18—Metals not determined; 19—Boundes of hydrochemical fields. Figures are Nos. of water sampling sites. (Except .7 and 784.0, which are altitudes in meters. VPS)


Q 1
D$_3^2$-C$_1$ 2
D$_1^2$-D$_2$ 3
S$_2$ 4
γ$_3$ 5
6
7
8
9
10
11
Cu 12
13
14
15
16
17
18
Mo
Cu
Pb
Ni
W
Ti
Mn
Sr
Zr
Ag
Kuskuk Mts.
γ$_3$
D$_2^1$-D$_2$
Ak-Bulak
Q
Cu
Karamys River
D$_3^2$+C$_1$
Murzatai
Urochische Kare Mula
Kairakty
Selstroi
Monatai Mts.
D$_1^2$-D$_2$
Upper Kai-rakty
Kaska-Kashkar
852.7
River Kairakty
S$_2$
Bes-Baldyk River
Abyk-Abasy
Kuldensyk
Urochische Uzen-Bulak
Kara-Zahl
Lake Kara-Saz
Kara-Saz River
19
20
21
22
23
24

gure 3, the underground waters representing the albitophyre beds of ontai and Dzhaksy-Tagaly Mountains carry a four-member complex the metals: Pb, Cu, Ag, Zr. Waters of the Kairakty River and the derground waters in the metamorphic schists at the Kairakty-Kara z water-divide, 8 km from the Kairakty lead-copper-barite deposit, rry Pb, Cu, and Ba. Waters of the Murzatai Sopka granitoids carry , V, Mn, Pb, Zr, and Sr.

Practically all of the above enumerated elements are detectable in natural waters of the Upper Kairakty deposit. These waters are nspicuous against the regional hydrochemical background due to ir high content of total metals (Figure 3).

Distribution (per cent as of the total found) and concentration of tals in the waters are not the same for the district as a whole and the mineralized part of the district (Tables 1 and 2). The occurnce of individual constituents is calculated as per cent of the samples th the given constituent relative to the total collected and analyzed mples (100%). The results presented in Table 1 show that the tallic constituents of the district waters fall into several groups, th respect to their occurrence.

The first group, copper, manganese, titanium, and strontium, is stributed most extensively both in the district and at the deposit. lybdenum (the second group) is found chiefly in waters of the posit but is also common in the waters of the district. Zirconium, d, zinc, and copper (the third group), common in waters of the disct, are relatively rare in waters of the deposit. Nickel, silver, nadium, and barium (the fourth group) are common locally in the strict but are rare in the waters of the deposit. Tungsten, yttrium d lanthanum (the fifth group) are found chiefly in waters of the desit but only in isolated cases in waters of the district. Tin and romium (the sixth group) are found in isolated cases, both in the strict and at the deposit. Gallium, zinc, and arsenic (the seventh oup) are not detected in waters of the deposit and are extremely rare waters of the district.

g. 3. Map of metals in underground and surface waters of the Upper Kairakty trict: 1—Alluvial, proluvial, and diluvial sediments; 2—Limestones, sandstones, fs, tuffites; 3—Albitophyre beds; 4—Sandstones, shales, effusive basic porphyrites d their tuffs; 5—Granite porphyries, intrusive quartz porphyries, felsite porphys; 6—Boundary of geologic complexes of rocks; 7—Lines of tectonic disturbances; Lead in waters, more than 5 × 10^{-3} mg/liter; 9—Vanadium in waters, more than 10^{-3} mg/liter; 10—Tungsten in waters, more than 1 × 10^{-2} mg/liter; 11—Aric in waters, more than 8 × 10^{-2} mg/liter; 12—Copper in waters, more than 10^{-3} mg/liter; 13—Manganese in waters, more than 2 × 10^{-3} mg/liter; 14—Modenum in waters, more than 5 × 10^{-3} mg/liter; 15—Barium in waters, more 4 × 10^{-2} mg/liter; 16—Nickel in waters, more than 5 × 10^{-3} mg/liter; 17—(Unerentiated-VPS) Metals in waters, more than 5 × 10^{-3} mg/liter; 18-Elements ected in waters; 19—Elements detected in loose sediments; 20—Elements deed in metamorphic rocks; 21—Elements detected in silts; 22—Copper; 23—Lead; -Tungsten. ("D" - Devonian; "C" - Cretaceous; "Q" - Quaternary; the mmas - intrusive bodies; "S" - Silurian. VPS)

Table 2 is a detailed version of Table 1, showing that not every element that may be common in the waters of the deposit or of the district may be regarded as an indicator element in the reconnaissance. It is essential for us to know the concentration distributions of the elements in the waters.

The metals background in waters, in our view, is expressed by their concentrations, as they are found regionally, away from the ore body. Proceeding from this definition of the term and from the data in the upper part of Table 2, the background concentrations of the metals may be taken as follows, in milligrams per liter:

$n \times 10^{-3}$, and lower, for Mo, Cu, Pb, Ni, Ag, V, and the total metals;
$n \times 10^{-2}$, and lower, for Zr, Mn, Ti, Ba;
$n \times 10^{-1}$, and lower, for Sr and Zn*;
lower than $n \times 10^{-2}$ for W.

Prospecting significance of this or that element is determined by three fundamental considerations:

1. Migration capacity (the abundance-distribution) of the element in the region and at the ore deposit.
2. Range of fluctuations in the amounts of the given element, in waters of the region and of the ore deposit.
3. State of development of the methods of determining the given element in waters.

The clearer the departures in the amounts of this or that element in waters of an ore body from the regional background, and the more extensive the given element distributed in waters of the region, or the more common the given element in waters of the ore deposit—the greater is its prospecting value, if its migration capacities are regionally low.

Absence of exact, simple, and rapid field methods of determining the given element in waters detracts significantly from the prospecting value of this element, all other things being the same.

In regard to the distribution-abundance, in the waters of our region and of the ore body, it should be possible to make use of the elements in Groups I, II, III and of some elements in Group IV. However, we may see, from the lower part of Table 2, that, with the exception of molybdenum and tungsten, the vast majority of the elements in these groups show no clear-cut variations, in waters of the ore body, from their regional background. Waters of the ore body are conspicuously different from the background only by their molybdenum and tungsten concentrations. And yet, the migration capacities of tungsten are much lower than those of molybdenum, in the hydrochemical environment of the area. The analytical methods for tungsten in waters are not as exact as the methods for molybdenum. Because of that, the per cent occurrence of tungsten is very low in the waters of the ore deposit, notwithstanding the fact that tungsten is the principal ore constituent in the ore body in question.

*Spectrographically

Thus it is only molybdenum, in the given hydrochemical environ-nt, that satisfies all of the criteria as an indicator element in the loration, and it may be recommended, therefore, as the indicator prospecting for the rare metal ores of the Upper Kairakty type, in region here discussed as well as in the hydrochemically analogous gions.

Hydrochemical molybdenum anomalies are zonal in their distribu-n at the Upper Kairakty deposit, as well as at other deposits in ntral Kazakhstan. The molybdenum content of waters varies from 10^{-3} to 8×10^{-2} mg Mo per liter. The highest concentrations are nd in magnesium and sodium-bicarbonate waters of the ore stock-rk itself and also in the vicinity of the ores, where the oxidation ocesses are most intensive (0.03 to 0.08 mg Mo per liter). Such lybdenum-high waters form the *inner zone of the geochemical omaly which represents the maximum of the mineralization.* The lybdenum content of waters varies from 5×10^{-3} to 2×10^{-2} mg/l. the remaining ritory of the posit, decreas- with distance m the zone of maximum neralization. ters within s range of lybdenum con-t form two nes, elongated the directions the sub-surface w—*the central l the outer* zones the geochemical omaly.

The central ne (0.01 to 0.02 Mo/l.) coin-les with the area the presently onomic ores, hough it is ngated and placed in the ection of the -surface flow rtheast and thwest). The er Zone of

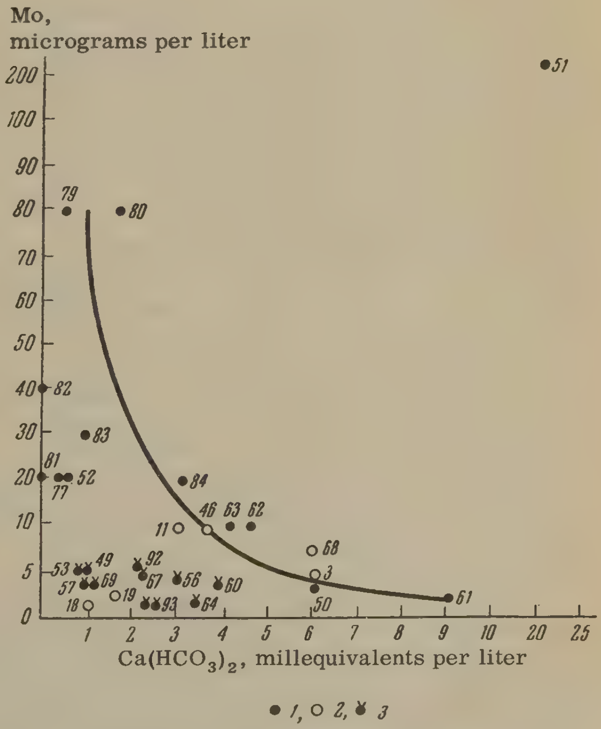


Figure 4. Distribution of molybdenum in waters as influenced by calcium bicarbonate: 1—underground waters in schists; 2—underground waters in eluvial-diluvial sediments; 3—mixed waters representing both schists and unconsolidated materials. Numbers on the diagram as sampling sites (as in Figures 1, 2 and 3—VPS).

the anomaly, embracing the territory of the primary halo of the ore, is elongated in the direction of the water flow, and is traceable for 1.2 to 1.5 km distance from the ore body (in the waters of Kairakty River). Within the boundaries of these zones, the lowest concentrations of molybdenum (5 x 10^{-3} mg/liter and lower) are found in waters which are formed by mixing of waters of the ore body and of the bicarbonate waters of the loose materials. This group of mixed waters is represented in the lower left corner of Figure 4, below the curve (Points 53, 49, 92, 67, 56, 60, 57, 69, 55, 93, 64). The ore body waters lose their molybdenum and the bicarbonate waters lose their calcium in the process of mixing (a co-precipitation).

This phenomenon must be taken into account in the representation of a hydrochemical anomaly, in accordance with our diagrams. Accordingly, the cores of the anomalies must be extended to include the areas containing sampling points 49, 53, 67, and 52. The outer zone of the anomaly must be enlarged, to include sampling points 65, 93, 60, and 57 (Figure 1).

2.4 x 10^{-1} mg/liter of molybdenum (sampling point 51) was found in the sodium sulfate saline waters of the eluvial-diluvial formations, in Severnyi Gully which is outside the mineralized zone. In this case, we are dealing with an accumulation of molybdenum in the water caused by the evaporation (a displaced spurious anomaly). The relative enrichment of such waters by molybdenum is low, amounting to a few thousandths or ten thousandths of one per cent, whereas the true enrichment of the percolating waters, with respect to molybdenum, in the ore field itself, varies from several thousandths to several hundredths of one per cent. We may distinguish between true and spuriou anomalies by conversion of the molybdenum content of waters to a relative basis.

It is evident from the foregoing data that studies of the distribution of molybdenum in waters enables us not only to identify the economically promising mineralized areas, against their regional hydrochemical background, but also to make differentiations within the promising area itself, depending on the intensity of the mineralization. However our interpretations must take into account the possibility of spurious anomalies as well as of a mixing of the waters which would result in a lowering of their molybdenum content.

The distribution of tungsten in waters of the deposit shows a measure of regularity, as indicated by Figure 1. The hydrochemical tungsten anomaly is displaced with respect to the ore body and may be traced in waters that appear outside the ore body boundaries, at the foot of Ak-Shoko Sopka. Thus tungsten, like sulfate, produces a clearly defined displaced anomaly in the area of accumulation of the salts that were leached out of the ore body. In our use of tungsten as a supplementary indicator element for tungsten ores of the Upper Kairakty type, we must take into account the possibility of displaced anomalies.

We may add a few words about the distribution of metals in high sul-
e waters. Not all of these waters (Figure 2) are correspondingly
h in the metals (Figure 3). Waters from the metamorphic schists
ntain sulfate anomalies, but their metal content is within the range of
background (Mt. Kushuk, Mt. Dzhaksy-Tagaly). Some waters con-
n both sulfate and metal anomalies, however (lead at sampling point
copper, lead, barium, vanadium at sampling point 38; molybdenum
vicinity of the Murzatai Sopka). At the same time, waters carrying
dinary amounts of sulfate may be anomalous in their metal content
rium at sampling points 39, 40; at Ak-Bulak—molybdenum, copper,
d lead; barium at sampling points 29 and 30; copper and lead at
mpling points 31, 32, 33, 34; copper and lead at sampling point 35;
d and molybdenum at sampling point 36). Indications of mineral-
tion of rocks are found in waters, in the metal anomalies of the
rresponding kind of metals, regardless of the sulfate content of the
ters. We are led to the conclusion therefore that metals in waters
the prime indicators of mineralization in the rocks, and also of
type of the mineralization, in our evaluation of the possibilities in
ospecting for ore deposits, in arid climatic environments. It is es-
ntial nevertheless to study the general chemical composition of the
ters, in order to determine the character of the hydrochemical
omalies and the forms and the size of the aqueous halo, as is evident
om the data already cited. This is particularly important in the
ognosis of mineralization in dealing with waters from unconsolidated
cks, as well as with surface waters, where there may be a develop-
nt of spurious anomalies, as the result of concentration of the
lutes by evaporation or as a consequence of the mixing of several
ters of different composition.

In conclusion, we should remark that the distribution of metals in
ters, in dissected terrains and in relatively humid climates is a
ar expression both of the quality of the regional metal content of
rocks and of the accumulations of metals in the rocks. Interpreta-
ns of hydrochemical findings are not especially involved and are
ll within the reach of geologist-surveyors.

A more complicated but a fundamentally analogous pattern of the
stribution of metals in waters develops also in the steppe plains of
Central Kazakhstan, in their arid and severely continental climate
bracing a large variety of hydrochemical environments.

Once again we must emphasize the high value of molybdenum in
ters, as the most reliable indicator element for rare metals, in
drochemical prospecting. It should be recognized also that the
oup of indicator elements must be expanded, as the result of further
dies in the methods of hydrochemical prospecting. Successes in
s direction, on the whole, are contingent on the progress with im-
ovements of analytical methods for the determination of metals in
ters.

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EQUILIBRIUM OF TWO LIQUID PHASES IN FLUOR-SILICATE SYSTEMS CONTAINING ALKALI METALS

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Abstract

(English abstract in original is identical with the translated conclusions, p. ..)

Our earlier studies [1, 2] defined the boundaries of the fields of miscible liquids in systems of the type of $MeF_2 - MeO - SiO_2$ and $F_2 - Al_2O_3 - SiO_2$.

Fused systems containing oxides of the alkali metals, so important m the geologic point of view, are especially interesting in investitions of the phenomena of the magmatic differentiation. According D. V. Greig [3], 3 to 4% of the alkali oxides is already sufficient to minate immiscibility in ternary systems of the $MeO - MeO_2 - SiO_2$ e.

We investigated the equilibrium area of the two liquid phases in the $F_2 - Na_2 - SiO_2$ system, so as to ascertain the effects of the alkali ides on the immiscibility in fused systems.

In magmatic melts, the oxides react with water, in all probability, th the formation of OH^- in many respects. It should be possible erefore to suggest that fluorine-silicate systems may be modeled by corresponding fused water-bearing systems of silicates.

One may suppose also that all of the metal oxides may be converted o the corresponding hydroxides, in fused systems of silicates, at gh pressures (according to the reaction $MeO + H_2O = Me(OH)_2$; ${}_2O + H_2O = 2\,MeOH$ or, in the ionic form: $O^{2-} + H_2O = 2OH^-$).

Behavior of such silicate systems (we may call them ''hydroxylicates'') should be modeled by fluorine-silicate systems consisting ly of the metal fluorides and of the dioxide of silicon. Binary sysns of this type ($MeF_2 - SiO_2$) were already investigated [4]. In a eviously published experimental study [2] of systems of the $MeF_2 - {}_2O_3 - SiO_2$ type, we attempted also to enquire into systems of the $F_2 - AlF_3 - SiO_2$ type. Our attempts yielded no results, because the ed mass containing AlF_3 would flow out of the sealed crucibles. It ved to be possible, however, to investigate systems of the $Me^{II}F_2 - {}^{I}F - SiO_2$ type.* The experimental procedures were described in

e^{II}–Mg, Sr, Ca, Ba; Me^{I}–Na, K).

earlier publications [1, 4]. The charge consisted of a finely ground mixture of chemically pure quartz, alkaline earth fluorides, and glass of the $Na_2O.SiO_2$ composition. The fluorides were prepared from chemically pure carbonates and hydrofluoric acid. The interaction, on heating of the mixtures containing fluoride with SiO_2 was as follows: $2\,MeF_2 + SiO_2 \rightleftharpoons SiF_4 + 2\,MeO$. Consequently, all of the systems here investigated were of the mutual type, Me^{II}, Me^{I}, Si‖F, O. One may be satisfied, however, for the sake of simplicity, with a representation of the experimental data in the form of ternary systems. Among the observed consequences of the mutual character of our systems, we should note the low index of refraction of the glasses that were formed from liquids rich in SiO_2. As already reported [1, 4], this is due to the solution of SiF_4 in such glasses.

SYSTEM $CaF_2 - Na_2O - SiO_2$

The charges included glass of composition $Na_2O.2\,SiO_2$ (purity checked by chemical analysis), as well as CaF_2 and SiO_2. Since $Na_2Si_2O_5$ is a hygroscopic substance, the mixture had to be dried prior to the fusion.

Table 1. Fusion in System $CaF_2 - Na_2O - SiO_2$

No. of charge and section	Composition of charge, per cent by weight			Temperature, °C	Time, minutes	Loss in weight of charge, % by wt.	Number of liquid phases	Index of refraction of SiO_2-rich glass
	CaF_2	Na_2O	SiO_2					
1 (I)	53.7	1.7	44.6	1520	15	0.7	2*	1.446 to 1.451
2 (I)	48.0	5.1	46.9	1495	12	0.5	2*	1.446 to 1.451
3 (I)	34.4	13.3	52.3	1495	12	0.8	1	
4 (I)	41.3	9.1	49.6	1485	15	0.6	2*	1.446 to 1.451
5 (I)	37.5	11.5	51.0	1450	15	0.3	2*	1.446 to 1.451
5 (I)	37.5	11.5	51.0	1430	15	0.5	nf**	
1 (II)	63.2	6.9	29.9	1450	15	1.3	nf**	
1 (II)	63.2	6.9	29.9	1540	15	0.6	2*	1.444 to 1.446
2 (II)	58.9	8.7	32.4	1540	15	0.7	2*	1.444 to 1.446
3 (II)	55.7	10.1	34.2	1495	15	0.5	2*	1.444 to 1.446
4 (II)	50.1	12.5	37.4	1440	15	0.6	nf**	
4 (II)	50.1	12.5	37.4	1495	15	0.9	2	
4 (II)	50.1	12.5	37.4	1460	15	0.6	2	
5 (II)	47.6	13.5	38.9	1495	15	0.6	1	
1(III)	25.4	5.4	69.2	1495	15	0.6	2*	1.444 to 1.446
2(III)	19.6	11.9	68.5	1495	15	0.7	1	
3(III)	22.8	8.5	68.7	1475	15	0.9	2*	1.444 to 1.446
3(III)	22.8	8.5	68.7	1450	15	0.4	2*	1.444 to 1.446
3(III)	22.8	8.5	68.7	1430	15	0.5	1	
4(III)	21.2	10.2	68.6	1475	15	0.9	1	
4(III)	21.2	10.2	68.6	1450	15	0.3	1	

*Two layers separated by a meniscus (elsewhere, the formation of two liquid phases was established by microscopic studies of immersed prepared materials).

**"nf" means "no fusion".

The drying was done by placing the molybdenum crucible with the arge inside a quartz test tube through which a stream of hydrogen s allowed to pass. The test tube was warmed for five to seven inutes over a gas burner. The crucible was sealed after cooling. e loss in the weight of the charge, after such drying, was about 1%. e area of immiscibility in the $CaF_2 - Na_2O - SiO_2$ system was investi-ted in three sections through the following points:

I 56.5% CaF_2 + 43.5% $SiO_2 - Na_2Si_2O_5$;
II 79.2% CaF_2 + 20.8% $SiO_2 - Na_2Si_2O_5$;
III 30.2% CaF_2 + 69.8% $SiO_2 - Na_2Si_2O_5$.

e results are presented in Table 1 and Figure 1. The lower temper-ure boundaries, for the formation of the two liquids, were determined r three points:

5 (I) about 1440° C (1430 to 1450° C)
4 (II) about 1450° C (1440 to 1460° C)
3 (III) about 1440° C (1430 to 1450° C)

As follows from our results, the area of immiscibility (Figure 1) is arkedly smaller, in the presence of Na_2O, than it is in the previously vestigated systems $CaF_2 - CaO - SiO_2$ [4], $CaF_2 - Al_2O_3 - SiO_2$ [2]. owever, the area of immiscible liquids is larger in the $CaF_2 - Na_2O -$ O_2 system than it is in the oxide system, $CaO - Na_2O - SiO_2$ investi-ted by D. V. Greig [3].

SYSTEMS $CaF_2 - NaF - SiO_2$ AND $MgF_2 - NaF - SiO_2$

The areas of immiscible liquids, in the system $CaF_2 - NaF - SiO_2$, ere studied in three sections:

I 10.5% CaF_2 + 89.5% SiO_2 - NaF;
II 49.6% CaF_2 + 50.4% SiO_2 - NaF;
III 79.6% CaF_2 + 24.6% SiO_2 - NaF.

he results of the fusions are esented in Table 2 and in igure 2.

As shown by the results, the ea of immiscible liquids in the ystem $CaF_2 - NaF - SiO_2$ is ppreciably larger than it is in e $CaF_2 - Na_2O - SiO_2$ system.

The lower temperature undaries for the formation of e two liquid phases were de-rmined for the boundary ints:

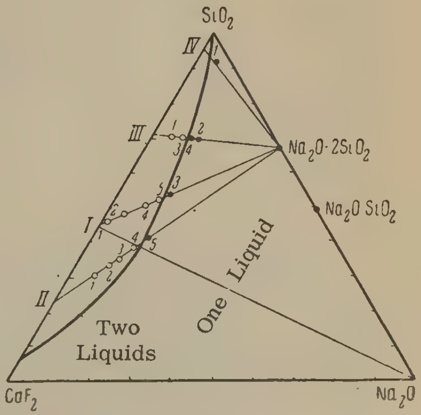


Fig. 1. The Equilibrium Field for Two Liquid Phases in System CaF_2-Na_2O-SiO_2, % by weight.

Table 2. Fusions in System CaF_2-NaF-SiO_2

No. of charge and section	Composition of charge, per cent by weight			Temperature, °C	Time, minutes	Loss in weight of charge, % by wt.	Number of liquid phases	Index of refraction of SiO_2-rich glass
	CaF_2	NaF	SiO_2					
1 (I)	10.4	1.1	88.5	1495	10	2.0	2	1.446 to 1.451
2 (I)	9.6	3.4	87.0	1450	15	0.5	2	
3 (I)	8.5	14.7	76.8	1450	10	0.5	1	
3 (I)	8.5	14.7	76.8	1360	12	0.7	2	
3 (I)	8.5	14.7	76.8	1280	12	0.8	nf**	
3 (I)	8.5	14.7	76.8	1315	12	0.6	2	
4 (I)	7.5	25.0	67.5	1495	10	1.7	1	
4 (I)	7.5	25.0	67.5	1270	12	0.5	1	
4 (I)	7.5	25.0	67.5	1250	12	0.5	nf**	
5 (I)	8.7	12.6	78.7	1450	10	0.5	1	
5 (I)	8.7	12.6	78.7	1410	10	0.3	1	
5 (I)	8.7	12.6	78.7	1385	10	0.3	2	1.444 to 1.451
5 (I)	8.7	12.6	78.7	1315	12	1.4	2	
6 (I)	8.5	18.5	73.0	1360	12	0.2	2	
6 (I)	8.5	18.5	73.0	1305	12	0.3	2	
6 (II)	8.5	18.5	73.0	1280	12	0.6	nf**	
1 (II)	39.7	19.9	40.4	1360	12	0.4	2	1.444 to 1.416
2 (II)	30.0	39.5	30.5	1270	12	0.9	1	
3 (II)	37.0	25.5	37.5	1360	12	0.9	2*	
3 (II)	37.0	25.5	37.5	1340	12	0.3	2	
4 (II)	33.7	32.1	34.2	1360	12	0.4	2*	
5 (II)	31.1	37.4	31.5	1360	12	0.7	1	
5 (II)	31.1	37.4	31.5	1305	12	0.5	2	
5 (II)	31.1	37.4	31.5	1270	12	0.4	2	
5 (II)	31.1	37.4	31.5	1250	12	0.8	nf**	
6 (II)	32.4	34.6	33.0	1360	12	0.7	2*	
6 (II)	32.4	34.6	33.0	1315	12	0.5	2*	
6 (II)	32.4	34.6	33.0	1260	12	0.9	nf**	
7 (II)	27.3	45.0	27.7	1270	12	0.7	2*	
7 (II)	27.3	45.0	27.7	1225	12	0.5	nf**	
8 (II)	29.1	41.4	29.5	1315	12	0.8	1	
8 (II)	29.1	41.4	29.5	1270	12	0.9	1	
1 (III)	55.6	30.2	14.2	1360	12	0.6	2*	1.446 to 1.451
2 (III)	49.5	37.8	12.7	1315	12	0.5	2*	
3 (III)	46.7	41.3	12.0	1270	12	0.8	2*	
4 (III)	45.1	43.3	11.6	1260	12	0.2	1	
4 (III)	45.1	43.3	11.6	1225	12	0.6	1	
4 (III)	45.1	43.3	11.6	1200	12	0.4	nf**	

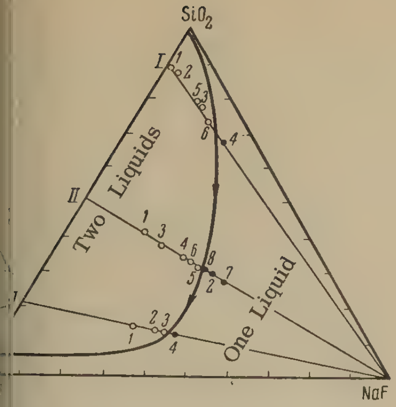
*See footnote, Table 1.
**nf = Not fused.

6 (I) about 1290° C (1280 to 1305° C);
5 (II) about 1260° C (1250 to 1270° C).

The upper temperature boundaries were determined for:

5 (I) about 1400° C (1385 to 1410° C);
5 (II) about 1330° C (1305 to 1360° C).

In all of our preparations here investigated, the quantity of SiO_2-rich liquid was one sixth to one seventh of the contents of the crucible. It is possible to maintain, therefore, that the critical point is somewhere in the vicinity of the SiO_2 apex. This is confirmed by microscopic studies of prepared materials from Section I. There is a



. 2. The Equilibrium Field of Liquid Phases in System CaF_2-F-SiO_2. % by weight.

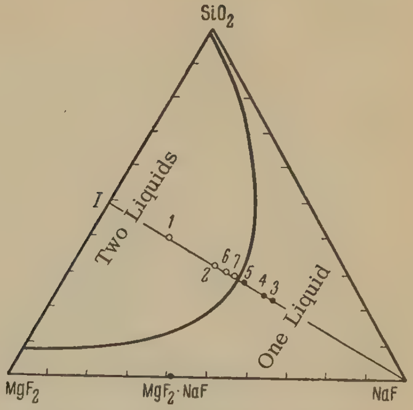


Fig. 3. The Equilibrium Field of Two Liquid Phases in System MgF_2-NaF-SiO_2. % by weight.

procal relation in the properties of the two liquid phases: an in-
ase in the crystallization capacity of the SiO_2-rich liquid and a con-
rent decrease in the same capacity of the SiO_2-poor liquid. As we
e closer to the boundary between the two immiscible liquids, the
lence of immiscibility becomes progressively less clear: the opti-
differences between the low-index glass (the SiO_2-rich liquid) and
disseminated rounded inclusions of the second phase (the SiO_2-poor

Table 3. Fusions in System MgF_2-NaF-SiO_2.

of ge l on	Composition of charge, per cent by weight MgF_2	NaF	SiO_2	Temperature, °C	Time, minutes	Loss in weight of charge, % by wt.	Number of liquid phases	Index of refraction SiO_2-rich glass
)	40.5	20.3	39.2	1400	12	1.8	2	1.437 to 1.441
)	32.8	35.6	31.6	1385	12	2.0	2	
)	32.8	35.6	31.6	1450	12	1.0	1	
)	32.8	35.6	31.6	1340	12	1.2	2	
)	32.8	35.6	31.6	1280	12	0.5	2	1.437 to 1.444
)	22.8	55.2	22.0	1280	12	0.7	1	
)	22.8	55.2	22.0	1290	12	0.9	1	
)	24.3	52.2	23.5	1290	12	0.5	1	
)	24.3	52.2	23.5	1270	12	1.3	1	
)	28.0	44.8	27.2	1260	12	2.2	1	
)	28.0	44.8	27.2	1290	12	2.0	1	
)	28.0	44.8	27.2	1225	12	1.0	1	
)	28.0	44.8	27.2	1190	12	0.9	nf**	
)	30.5	39.9	29.6	1239	12	2.7	nf**	
)	30.5	39.9	29.6	1305	12	2.4	2*	1.446 to 1.451
	29.3	42.3	28.4	1290	12	1.7	2*	1.446 to 1.451
)	29.3	42.3	28.4	1270	12	1.5	nf**	
)	29.3	42.3	28.4	1360	12	0.4	1	

footnote, Table 1.
fusion.

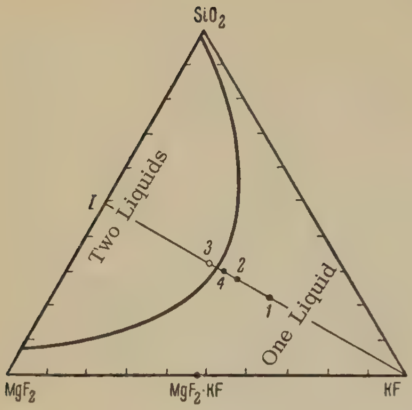


Fig. 4. The equilibrium field of two liquid phases in system MgF_2-KF-SiO_2. % by weight.

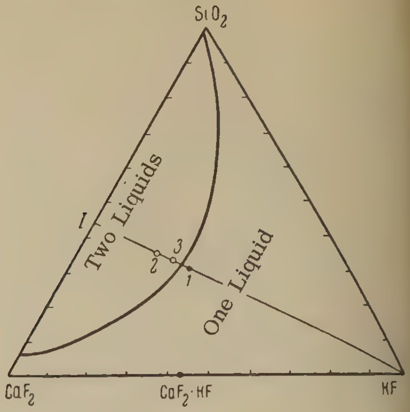


Fig. 5. The equilibrium field of two liquid phases in system CaF_2-KF-SiO_2. % by weight.

liquid) become less definite. After heat-treating materials from the vicinity of the boundary, the SiO_2-rich liquid has a shagreened appearance—brown fragments with the sub-microscopic crystallization.

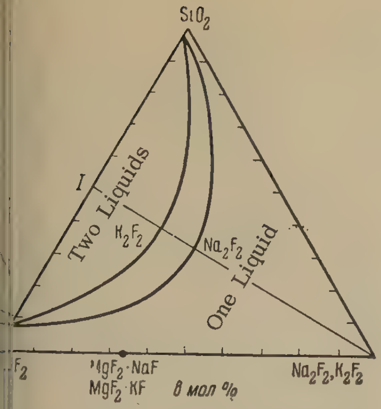
Table 4. Fusions in System CaF_2-KF-SiO_2

No. of charge and section	Composition of charge, per cent by weight			Temperature, °C	Time, minutes	Loss in weight of charge, % by wt.	Number of liquid phases	Index of refraction
	CaF_2	KF	SiO_2					
1 (I)	39.5	30.0	30.5	1260	15	0.9	1	-
1 (I)	39.5	30.0	30.5	1200	15	0.4	nf**	-
2 (I)	45.2	20.0	34.8	1280	15	0.6	2	-
2 (I)	45.2	20.0	34.8	1210	15	0.3	nf**	-
2 (I)	45.2	20.0	34.8	1260	15	1.3	2	-
2 (I)	45.2	20.0	34.8	1245	15	0.7	nf**	-
3 (I)	42.4	25.0	32.6	1210	15	0.9	nf**	-
3 (I)	42.4	25.0	32.6	1280	15	1.2	2*	

*See Table 1 for footnote.
**"nf" means "no fusion".

SYSTEMS MgF_2 - KF - SiO_2 AND CaF_2 - KF - SiO_2

As distinct from NaF, KF is a strongly hygroscopic substance and, for that reason, the charge had to be mixed in a dry chamber. Otherwise, the crucibles with the charge were treated in the same way as in the CaF_2 - Na_2O - SiO_2 fusions.



ig. 6. The Equilibrium Fields
Two Liquid Phases in Systems
gF_2-Na_2F_2-SiO_2 and MgF_2-K_2F_2-
O_2; molecule-per cent.

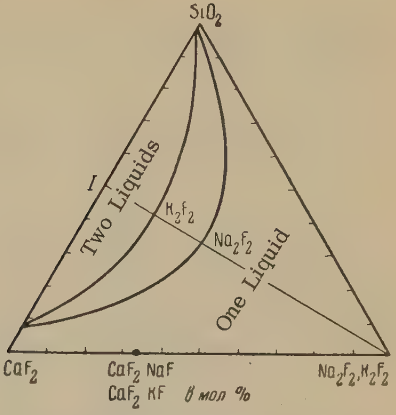


Fig. 7. The Equilibrium Fields of Two Liquid Phases in Systems CaF_2- Na_2F -SiO_2 and CaF_2-K_2F_2-SiO_2; molecule-per cent.

Boundaries of the fields of immiscibility were determined in the
lowing sections:
50.9% MgF_2 + 49.1% SiO_2 - KF;
56.5% CaF_2 + 43.5% SiO_2 - KF.
e results are presented in Tables 4 and 5 and in Figures 6, 7, and 8.
e lower temperature boundary in the CaF_2 - KF - SiO_2 system is de-
mined to be in the vicinity of 1205° C (between 1190 and 1220° C),
the Composition 3 (I). The field of immiscibility decreases in size,
ause of the presence of K^+, as may be seen from comparisons be-
en the liquid phase fields in the MgF_2 - KF - SiO_2 and the CaF_2 - KF -
$_2$ systems with the corresponding systems containing NaF (Figures
nd 7).

The field of immiscibility becomes smaller also when Mg is re-
ced by Ca, as illustrated by Figure 8, which is a comparison between

Table 5. Fusion in System MgF_2-KF-SiO_2

. of arge nd tion	Composition of charge, per cent by weight.			Temperature, °C	Time, minutes	Loss in weight of charge % by wt.	Number of liquid phases
	MgF_2	KF	SiO_2				
(I)	22.8	55.1	22.1	1225	12	0.9	1
(I)	28.2	44.5	27.3	1210	12	0.8	1
(I)	32.9	35.2	31.9	1235	12	1.0	2*
(I)	30.5	40.0	29.5	1225	12	0.6	1

e footnote for Table 1.

the boundaries of the immiscible liquids, shown as molecular per cent.

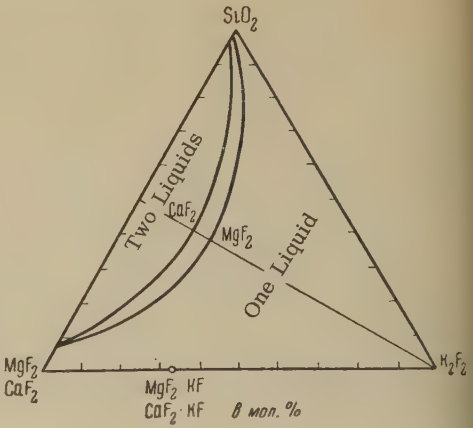


Fig. 8. The Equilibrium Fields of Two Liquid Phases in Systems MgF_2-K_2F_2-SiO_2 and CaF_2-K_2F_2-SiO_2; molecule-per cent.

SYSTEMS SrF_2-NaF-SiO_2 AND BaF_2-NaF-SiO_2

Boundaries of the fields of stratification were determined by us after studies of the following profiles:

59.3% SrF_2 + 40.7% SiO_2-NaF;
74.5% BaF_2 + 25.5% SiO_2-NaF.

Results of the fusions are reported in Tables 6 and 7 and are represented in Figures 9 and 10. The temperature boundaries were established for the boundary points 1 (I), although their determination was made difficult by the proximity of the Composition 2 (I) to the boundary, in the SrF_2-NaF-SiO_2 System. The upper temperature for the Composition 3 (I), in the BaF_2-NaF-SiO_2 System was also established.

The lower temperature boundaries are:
1 (I) about 1260° C (between 1245 and 1270° C);
4 (I) about 1250° C (between 1235 and 1250° C);
the upper ones:
1 (I) about 1315° C (between 1305 and 1325° C);
4 (I) about 1310° C (between 1280 and 1340° C).

Table 6. Fusions in System SrF_2-NaF-SiO_2

No. of charge and section	Composition of charge, per cent by weight			Temperature, °C	Time, minutes	Loss in weight of charge, % by wt.	Number of liquid phases	Index of refraction of SiO_2-rich glass
	SrF_2	NaF	SiO_2					
1 (I)	41.5	29.9	28.6	1305	12	1.8	2*	
1 (I)	41.5	29.9	28.6	1225	12	0.9	nf**	
1 (I)	41.5	29.9	28.6	1270	12	2.1	2*	1.437 to 1.446
1 (I)	41.5	29.9	28.6	1245	12	1.3	nf**	
1 (I)	41.5	29.9	28.6	1325	12	0.7	1	
2 (I)	40.3	32.0	27.7	1270	12	0.9	2*	1.437 to 1.444
3 (I)	36.8	37.2	26.0	1245	12	0.5	nf**	

*See footnote, Table 1.
**"nf" means "no fusion".

Table 7. Fusions in the BaF_2-F-SiO_2 System

Io. of harge and ction	Composition of charge, per cent by weight			Temperature, °C	Time, minutes	Loss in weight of charge % by wt.	Number of liquid phases	Index of refraction of SiO_2-rich glass
	BaF_2	SiO_2	NaF					
1 (I)	59.5	20.4	20.1	1450	12	0.4	1	
1 (I)	59.5	20.4	20.1	1400	12	1.3	1	
1 (I)	59.5	20.4	20.1	1245	12	0.6	1	
1 (I)	59.5	20.4	20.1	1220	12	0.5	nf**	
2 (I)	67.0	22.9	10.1	1475	12	1.5	1	
2 (I)	67.0	22.9	10.1	1385	12	1.5	1	
2 (I)	67.0	22.9	10.1	1280	12	0.9	2*	1.444 to 1.451
3 (I)	63.3	21.6	15.1	1280	12	0.4	2*	1.444 to 1.451
3 (I)	63.3	21.6	15.1	1340	12	0.8	1	
4 (I)	61.9	21.1	17.0	1200	12	1.0	nf**	
4 (I)	61.9	21.1	17.0	1260	12	1.6	2	
4 (I)	61.9	21.1	17.0	1235	12	0.6	nf**	
4 (I)	61.9	21.1	17.0	1315	12	0.7	1	

*See footnote Table 1.

*“nf” means “no fusion”.

Quantities of the SiO_2-rich liquid are much smaller than quantities the SiO_2-poor liquid, in all of the cases studied by us, both in the F_2 - NaF - SiO_2 and in the BaF_2 - NaF - SiO_2 systems.

It is evident that the critical points are situated near the SiO_2 apex, systems of the MeF_2 - NaF - SiO_2 type we had studied. We were not ıccessful in a more exact determination of the critical points, which essential for comparisons of their positions in different systems.

Boundaries of the fields of immiscibility in systems of the $Me^{II}F_2$ - $e^{I}F_2$ - SiO_2 type (in molecular-per cent) are presented in Table 8.

As shown by these findings, the width of the liquid two-phase field related to the radius and the charge of the cation. Thus, as the ıtio between the nic radius and the ılence becomes reater, in the ations, the area of e fields of im- iscible liquids ecomes smaller, systems of the eF_2 - MeO - SiO_2), MeF_2 - Al_2O_3 - O_2 types which ere investigated us.

By making use the boundaries tween the two

Table 8. Points at the Boundary of the Fields of Immiscibility; Equimolecular Section (50% $Me^{II}F_2$ + 50% $SiO_2Me_2{}^{I}F_2$)

System	Ratio of radius of divalent cations to valence	Me_2F_2, Mol-per cent
MgF_2-Na_2F_2-SiO_2*	0.375	36.0
CaF_2-Na_2F_2-SiO_2*	0.505	34.6
SrF_2-Na_2F_2-SiO_2	0.59	32.3
BaF_2-Na_2F_2-SiO_2*	0.68	24.2
MgF_2-$K_2F_2SiO_2$*	0.375	24.4
CaF_2-K_2F_2-SiO_2*	0.505	18.0

*Ionic radii: Na+ - 0.98 Å; K+ - 1.33 Å.

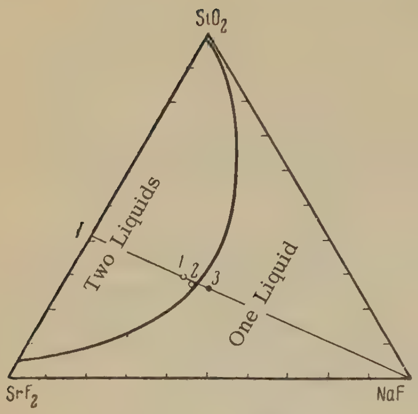


Fig. 9. The Equilibrium Field of Two Liquid Phases in System SrF_2-NaF-SiO_2; per cent by weight.

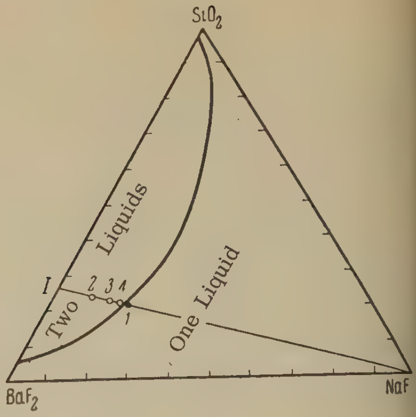


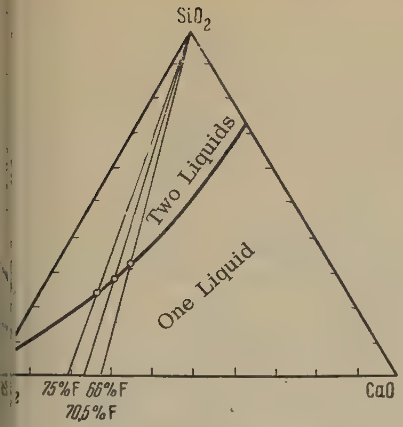
Fig. 10. The Equilibrium Field of Two Liquid Phases in System BaF_2-NaF-SiO_2; per cent by weight.

liquid phases in the systems CaF_2 - CaO - SiO_2 [4], CaF_2 - Na_2O - SiO_2, and CaF_2 - NaF - SiO_2, we are enabled to define the areas of immiscibility resulting from a partial replacement of O^{2-} by F^-. For this purpose, the equivalent ratios of O^{2-} to F^- were calculated for the boundary points of three profiles we had studied in the system CaF_2 - Na_2O - SiO_2, as follows: 75% F^- and 25% O^{2-}, Section I; 77% F^- and 23% O^{2-}, Section II; 67% F^- and 33% O^{2-}, Section III.

In the system CaF_2 - CaO - SiO_2, on the CaF_2 - CaO side, we marked the points corresponding to the above F^-:O^{2-} ratios, (Figure 11). Intersections of lines connecting these points with the SiO_2 apex and the boundary of the area of immiscibility in the ternary system give us the field boundaries of the two liquid phases, in the CaO-SiO_2 systems where the O^{2-} is partially replaced by F^- (77, 75, 67%).

In harmony with these results, Figure 12 represents the boundaries of the fields of immiscible liquids in the system CaO - Na_2O - SiO_2, at 100, 77, 75, and 67% replacement of O^{2-} by F^- . The 100% replacement corresponds to the boundary of the field of the two immiscible liquid phases in the system CaF_2 - NaF - SiO_2. For the sake of comparisons, the same diagram shows also the immiscibility field boundaries in the system CaO - Na_2O - SiO_2 [3] corresponding to the wholly oxygen system (0% F^-).

The results of the present study enable us to make certain suggestions regarding the liquidation phenomena in magmatic processes. As shown in Figure 12, the replacement of O^{2-} by F^- causes an appreciable expansion of the field of immiscible liquids. This field become especially large as the replacement of O_2^- by F^- comes close to 100%



g. 11. The Equilibrium Field of
o Liquid Phases in System CaF_2-
O-SiO_2; per cent by weight.

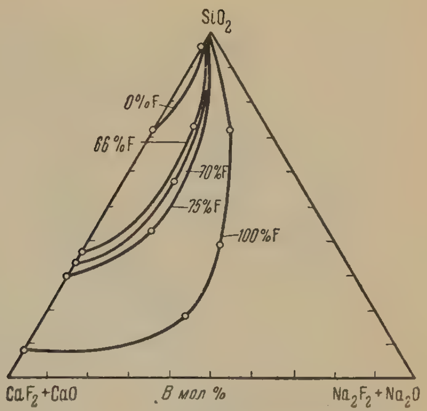


Fig. 12. The Equilibrium Field of Two Liquid Phases in System CaF_2-Na_2O-SiO_2 at 0, 66, 75, and 100% replacement of O^{2-} by F^- (mol-per cent.)

While making use of these data in modeling aqueous-silicate mag-
tic melts, one must make an evaluation of the possibilities of exist-
ce of such melts where practically all of the oxygen ions become
droxid ions because of their interactions with water. We have in
nd only the oxygen which is bound stoichiometrically with the metals
not with silicon (i.e., all of the oxygen of the melt, except the
ichiometrically bound oxygen in the SiO_2).

The data on solubility of water in silicate melts available in the
erature by no means contradict our supposition regarding the exist-
ce of such hydroxide-silicate melts. They tend to support it. Indeed,
cording to the measurements by R. W. Goranson [6], there is a grad-
l retardation in the increase of the solubility of water in melted
dspars and granites, as the concentration of water increases at in-
easing pressures. The solubility of water increases to about 9.7%
5000 atm., whereupon any further increases in pressure cause
latively small increases in the solubility of water in the melts. A
-calculation of Goranson's data on the solubility maximum for water
such melts as OH^- shows practically a full conversion (about 80 to
%) of oxygen to hydroxide: $O^{2-} + H_2O \longrightarrow 2\,OH^-$.

Therein lies the most probable explanation of the insignificant in-
ease in the solubility of water at further increases of the pressure.
follows, therefore, that magmatic melts forming at high water
essures should be modeled by fluorine-silicate systems in which
degree of replacement of O^{2-} by F^- is close to 100%. Figure 13
the well-known diagram of Greig, with the coordinates of CaO +
O + FeO; Na_2O + K_2O + Al_2O_3; SiO_2, and the plotted average com-
sition of igneous rocks in the stratified field of dry silicate melts,
cording to the data of Daly.

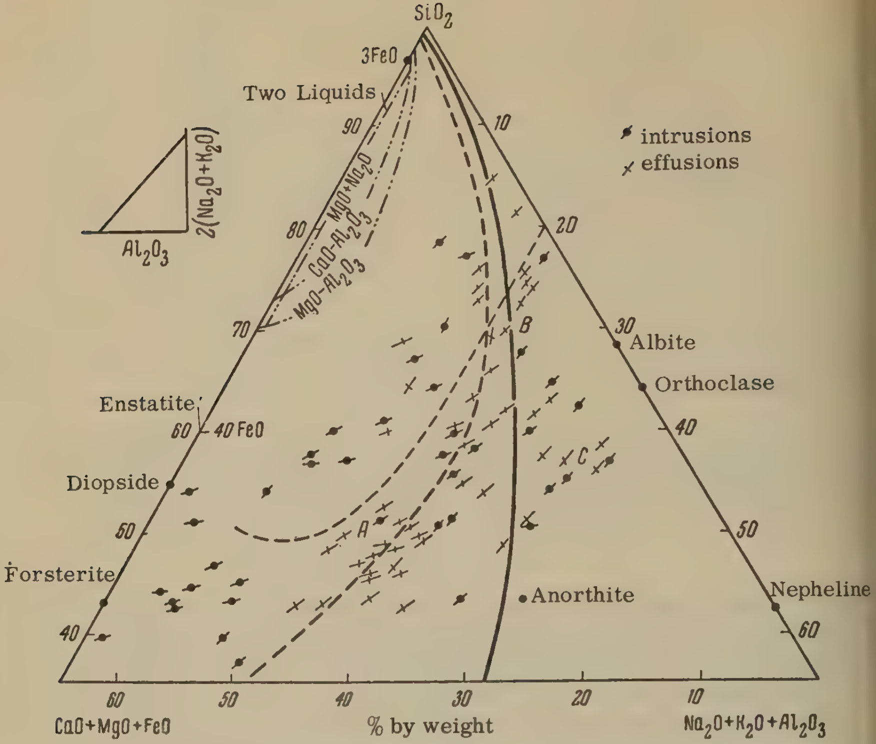


Fig. 13. Diagram illustrating relationship of the immiscible compositions of igneous rocks, according to Greig.

Compositions of igneous rocks are plotted after conversion of the results to water-free basis and the addition, to the sum of CaO + MgO + FeO, of constituents not shown on the diagram. The points below the dotted line represent the averages, according to Daly; the points above the dotted lines are examples of the extremes, from Washington's tables. The alkali:alumina ratio is indicated by the slope of the line through the given point, as shown in the small diagram, in the upper left corner. The heavy dotted line marks the field of immiscibility, as defined by D. P. Grigorev's data. The two-liquid field is indicated by the solid line, based on the present study of the $CaO-Na_2O-SiO_2$ system in which all of the metal-bound oxygen is replaced by fluorine. ''A''—basalt, gabbro; ''B''—rhyolite, granite; ''C''—phonolite, nepheline syenite.

Greig showed in the same diagram the extremes of the composition of rocks taken from Washington's tables (the points above the dotted line). All of these compositions are far away from the fields of immiscibility and D. V. Greig concludes accordingly that liquation phenomena are impossible in magmatic melts (unless substantial changes are to be caused by water or by some other constituents, still unknown

The field of possible immiscibility has been expanded considerably by D. P. Grigorev [5], who employed fluorine-silicate melts as model

aqueous silicate melts for the first time. According to his data,
field of immiscibility may be defined just as it is shown on Greig's
gram by the heavy dotted line. Our findings regarding the boundary
he area of immiscibility in the $CaO - Na_2O - SiO_2$ system, after the
lacement of all O^{2-} by F^-, are plotted as a solid line on Greig's
gram. The field of immiscibility, as defined by us, includes most
he composition types of rocks. It should be taken into account,
reover, that our data apply also to the $CaO - Na_2O - SiO_2$ system.*
A still greater expansion of the two-phase (liquid) equilibrium field
uld take place in analogous systems containing MgO or FeO in
ce of CaO and Al_2O_3 in place of Na_2O. At the same time, it must be
phasized once again that a complete replacement of O^{2-} by F^- may
del aqueous silicate systems existing at very high water pressures.
nsequently, the boundary of the field of stratification, as plotted by
on Greig's diagram, corresponds probably to the largest possible
e of the two-liquid field (for systems containing Ca, Na, and SiO_2).
Thus the results obtained in our present study are conducive to the
a that there is a possibility of immiscibility phenomena in mag-
tic processes.

In conclusion, we wish to thank A. I. Tsvetkov, Doctor of Geologic-
neralogic Sciences, for his many valuable suggestions.

CONCLUSIONS

1) The boundary of the region of two liquid phases in the system of
$F_2 - Na_2O - SiO_2$ has been established.

2) The boundaries of the regions of two liquid phases in the sys-
ns: $MgF_2 - NaF - SiO_2$, $CaF_2 - NaF - SiO_2$, $SrF_2 - NaF - SiO_2$, $BaF_2 -$
$F_2 - SiO_2$, $MgF_2 - KF - SiO_2$, $CaF_2 - KF - SiO_2$ have been established.
area of the immiscibility regions increases with the decrease of
ratio of the cation radius to valency.

3) The boundaries of the regions of immiscible liquids in the sys-
CaF_2, $CaO - Na_2F_2$, $Na_2O - SiO_2$ have been established, O^{2-} partly
ng replaced by OH^-.

4) The suggestion has been made that the system formed by SiO_2
fluorides of metals model such aqueous silicate melts in which,
ng to the interaction with water at high pressures, all the O^{2-} are
laced by OH^-.

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hout the replacement of its oxygen ions by flouride? VPS

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PARAGENESES OF LIME SKARNS IN THE TAEZHNOE MAGNESIAN SKARN IRON ORE DEPOSIT IN THE ARCHEAN OF THE ALDAN PLITA*

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Abstract

The high-temperature, postmagmatic replacement of dolomites has led to development of two metasomatic facies: the magnesium and lime infiltra- skarns. The dolomite beds and the aluminium-silicate rocks which are ctly adjacent to them are replaced by magnesium skarns. The somewhat ote aluminium-silicate rocks are replaced by lime skarns.

The lime skarns show that their great variety is caused by the inconstant linity and the oxidation-reducation conditions. The chemical activity of in solution was high but showed greater constancy. The dependence of the geneses on the chemical potentials of potassium and oxygen in solution is ted after D. S. Korzhinsky's method, the constancy of T, P and of chemical ntials of other quite mobile components (FeO, Na_2O, MgO, et al.) being ad- ed. Examples of skarnization of aluminium-silicate rocks under various itions of alkalinity and oxidizing-reducing conditions are considered.

The Taezhnoe deposit is situated in the Aldan District of the SSR.** The deposit is associated with an intricately faulted body olomitic marbles interbedded with amphibolites and leucocratic nites and related genetically to alaskite intrusions. A high- perature, post-magmatic replacement of the dolomitic marbles led to the development of two metasomatic facies at the site: magnesian skarns (the preponderant type), and b) limy skarns. The owing relationship has been established, in reference to their posi- s with respect to the dolomitic marbles.

The magnesian skarns (phlogopite, ludwigite, forsterite, diopside,), as such, replace the dolomites and the schists directly adjoining dolomites, whereas the limy skarns replace only "packets"* of ists at some distance from the dolomites. These differences are to the greater mobility of calcium, which enables calcium to go h farther than magnesium as the solutions are being filtered ugh the dolomitic marbles; the bulk of magnesium is retained in the dolomitic beds.

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ctonically, Plita is a part of a platform where the crystalline base is over- n by horizontally bedded or very gently folded thick series of sediments. VPS

e Yakut Autonomous Socialist Soviet Republic. VPS

The characteristics apply also to the distribution of the ores: the magnesian skarn ores (forsterite-magnetite, phlogopite-magnetite, ludwigite-magnetite, etc.) are formed in place of the dolomites, whereas the limy-skarn ores (salite-magnetite) are formed only in place of the aluminosilicate rocks (in the zones of the precipitation of calcium coming out of the dolomites), in an association with the limy skarns.

The bulk of the magnetic ores of the deposit is associated with the magnesian skarns, and replaces selectively the beds of dolomitic marbles. The magnetitic mineralization is related to the limy skarns within the "packets" of schist overlying the dolomites and is limited in its extent.

The principal minerals of the limy skarns are andradite, clinopyroxene, plagioclase or scapolite (50 to 80% meionite), orthoclase, quartz with calcite, and magnetite. Sphene and apatite may be noted among the subordinate minerals. Some late minerals may also be found: epidote, tremolite, and others. Andradite has a complex chemical composition, according to D. P. Serdyuchenko [3] (Chemical Analysis No. 1, Borehole 15): 73.18 per cent andradite, 14.04 grossularite, 7.80 of the molecule $Fe_2^{3+}Fe_3[(Si, Ti)O_4]_3$, 3.79 almandite, 0.67 spessartite, and 0.52 pyrope. This mineral is associated with pyroxenes of different kinds (salites and clinopyroxenes resembling hedenbergite in their iron content). The most highly ferruginous clinopyroxenes are characterized by the reverse adsorption order $X > Y > Z$ (X is dark green; Y, green; Z, yellow green) and by a noncoincidence of the ellipsoid axes of the absorption with the axes of the optical indicatrix. Not uncommonly the pyroxene contains a dense network of hematite platelets. The chemical analysis of this pyroxene ($\gamma = 1.757$; $\alpha = 1.732$; $2V = 71°$; $c:Z = 54°$) from the Taezhnoe, was placed at my disposal by L. I. Shabynin (No. 2171/6923, K-25), and makes it possible to express the results as mol per cents:

$$74.1\ Ca(Mg,Fe)Si_2O_6;\ 9.3\ CaAl_2SiO_6;\ 4.6\ CaFe^{2+}Si_2O_6;$$
$$0.9\ NaFe^{3+}Si_2O_6;\ 11.1\ 2Fe_2O_3$$

Examination of the parageneses in the limy skarns shows that the large number of their varieties is due to the lack of constancy in the alkalinity and in the oxidizing-reducing environments, since the parageneses differ among themselves both in their content of the alkalies and in the state of oxidation of their iron. Their formation was taking place in a highly ferruginous environment which was more constant, as such, than the alkalinity and the oxidizing environment. Thus for examples, two types of paragenesis are developed extensively at the site: a) ferruginous clinopyroxene (Px) with plagioclase (Pl) or scapolite (Sc), and b) andradite (Andr) with orthoclase (Or). They

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*"Pachka" ("packets") in this case probably means relatively thin bodies of schists. VPS

interrelated through the following reaction (the inert constituents
Al, Si) are equalized):

$$.23\ Pl_{40} + 5.0\ Px + (2.456\ FeO_{2/3} + 2.146\ KO_{1/2}) = 2.146\ Or + 1.92\ Andr + (2.50\ FeO + 0.738\ NaO_{1/2} + 1.0\ MgO)$$

Table 1

	$AlO_{3/2}$	CaO	SiO_2	FeO	$FeO_{3/2}$	MgO
pyroxene (Px); emical Analysis 2171	0.2	0.9	1.8	0.5	0.2	0.2
adite (Andr) emical Analysis 1C`	0.3	2.6	3.0	0.1	1.8	0.0

the sake of calculations involved in this reaction, and in the
rs, compositions of the clinopyroxene and the andradite are shown
able 1, as was indicated by the chemical analyses here cited.
ompositions of the rest of the minerals correspond to their the-
ical formulas. As shown by the reaction, on transition from one
genesis to another, an absorption (or a liberation) of the alkalies
a reduction (or an oxidation) of iron takes place, although the
amount of iron in the system remains practically unchanged.
"ferruginosity" of the system is not an equilibrium factor
efore, in the reaction in question, because both the left and the
t parts of the equation represent one and the same amount of

he dependence of parageneses in limy skarns on alkalinity (the
nical potential of potassium) and on chemical potential of oxygen
e solution is represented in Figure 1, a diagram made by
Korzhinskii's method [1, 2].* The diagram is representative of
tant temperature, pressure, and chemical potentials of the entirely
ile constituents: FeO, Na_2O, MgO.
he following relationships between chemical potentials of oxygen
iron were utilized in the construction of the diagram:

$$FeO_{3/2} = \mu_{FeO} + \frac{1}{2}\mu_o \quad \text{or, if } \mu_{FeO} = \text{const.},\ \mu_{FeO_{3/2}} = \text{const.} + \frac{1}{2}\mu_o\ .$$

teractions between minerals in limy skarns may be generalized
llows:

$$A + B + K\ (KO_{1/2}) = C + D + f\ (FeO_{3/2}),$$

lso *Geochemistry* (1), 1958, p. 57.

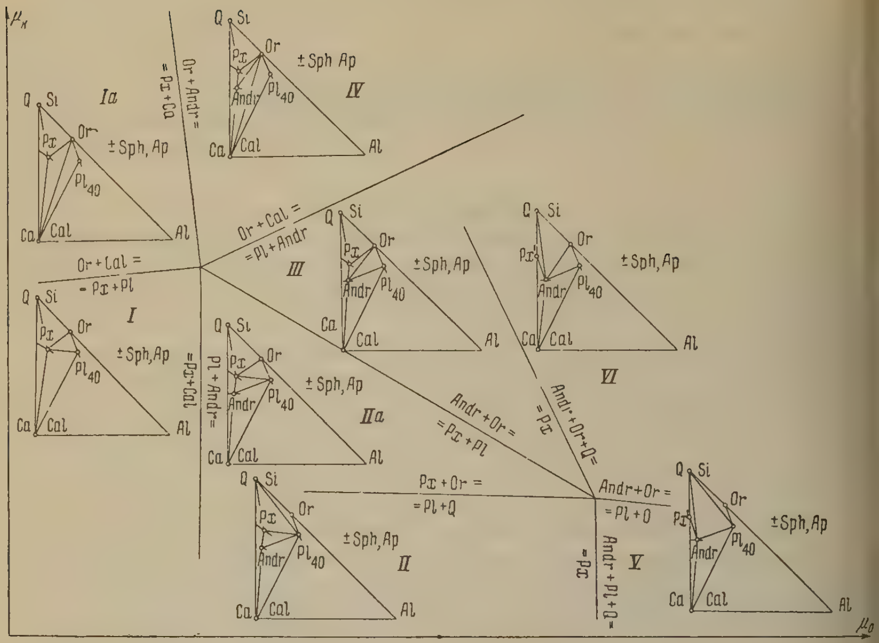

Fig. 1. Diagram of Chemical Potentials of Potassium and Oxygen for Limy Skarns of the Taezhnoe Deposit: Andr.—andradite; Ap.—apatite; Cal.—calcite; Pl_{40} —plagioclase An_{40}; Or.—orthoclase; Px—clinopyroxene resembling hedenbergite in its ferruginousness; Q—quartz; Sph.—sphene.

and the Mass Action Law, in its logarithmic form, for these reactions, may be expressed as:

$$K\mu_{KO_{1/2}} = f\mu_{FeO_{3/2}} + \text{const.}' = f(\text{const.} + \frac{1}{2}\mu_0) + \text{const.}'$$

$$= \frac{f}{2}\mu_0 + \text{const.}''; \quad \frac{d\mu_{KO_{1/2}}}{d\mu_0} = \frac{f}{2K} = \tan\alpha$$

where d is the angle formed by the reaction lines with the μ_0 axis of the diagram (Figure 1).

Fields of the diagram, identified by the Roman numerals, represent the paragenetic groups corresponding to the different environments, as characterized by their alkalinity and the oxidation potential. Groups I and Ia (low oxygen potential) are characteristically absent in the andradite parageneses. Groups II, IIa, III, and IV represent environments with a moderate activity of oxygen. In these groups, where alkalinity is low, orthoclase is associated with plagioclase (scapolite) and quartz (I). As the alkalinity increases, the following parageneses become stable successively: orthoclase-pyroxene (IIa), orthoclase-andradite

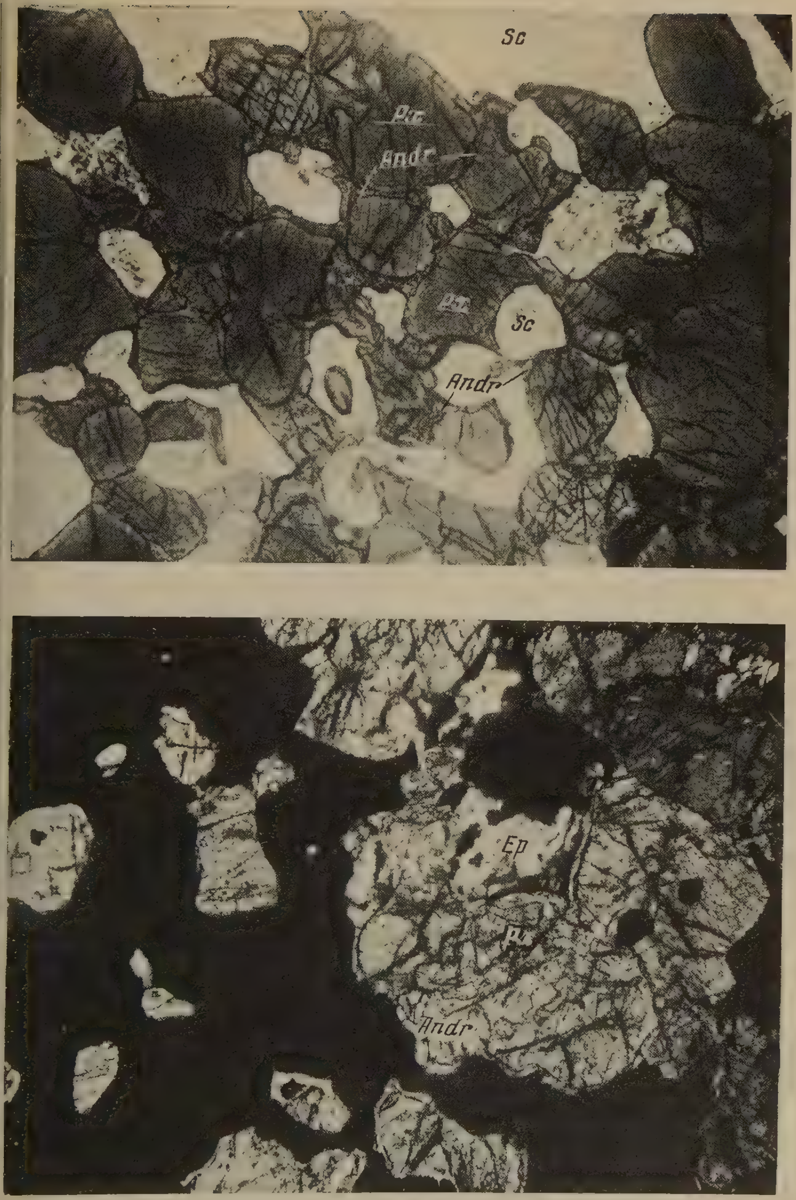

Fig. 2. Replacement of Pyroxene - Scapolite Rock by Andradite. Observe the andradite overgrowth on the grains of pyroxene and the occurrence of andradite along the boundaries between grains of pyroxene and magnetite. Section 2049, K-75. 46 X. One-nicol photograph.

(III), and orthoclase-calcite (IV). This dependence of the orthoclase parageneses, in limy skarns, on the alkalinity, established by D. S. Korzhinskii, is generally known. Groups V and VI represent environments with a high activity of oxygen. The andradite-quartz paragenesis, during the high-temperature stage, is possible only within these latter groups. As shown in the diagram, the andradite-quartz paragenesis (± Or or ± Pl) excludes the association of the pyroxene type (Px) which was assumed in the calculations of the reaction. However, there is a possibility of relatively low-alumina clinopyroxenes (Px') in the parageneses, since appreciable proportions (13 to 40%) of the grossularite molecule are always present in the high-temperature andradites in these skarns. For the same reason, presence of andradite in the rocks does not exclude the clinopyroxene (Px')-calcite paragenesis.

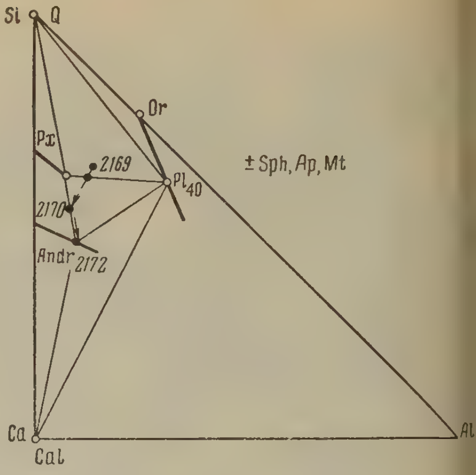

Fig. 3. Parageneses of Limy Skarns. Group II. Composition of rocks corresponds to the K-25 samples: 2170—Pyroxene-andradite skarn with areas of single-mineral andraditic skarn. Plotted according the Chemical Analysis No. 2170/6697; 2172—Single-mineral andraditic skarn; 2169—Pyroxene-plagioclase rock, locally with magnetite. Arrows indicate the replacement sequence.

The most common parageneses in the limy skarns of the Taezhnoe correspond to groups II and IIa. Parageneses in groups III and IV are also common. The others are relatively rare.

Figure 1 enables us to systematize the replacement of limy skarns by aluminosilicate rocks (schists, migmatites, and pegmatites) at the Taezhnoe, in accordance with the environments of the replacements.

If primary diopside (Di), with the ferruginosity of 10 to 30%, is present in the rock undergoing the replacement, the process begins with the change in the composition of the rock. The diopside begins to be replaced by the previously described dark green clinopyroxene:

$$\mathrm{Di} + (0.5\ \mathrm{FeO} + 0.1\ \mathrm{Fe_2O_3} + 0.1\ \mathrm{Al_2O_3}) = \mathrm{Px} + (0.6\ \mathrm{MgO});$$

$$\mathrm{CaO} \cdot (0.9\ \mathrm{MgO} \cdot 0.1\ \mathrm{FeO}) \cdot 2\ \mathrm{SiO_2} + (0.5\ \mathrm{FeO} + 0.13\ \mathrm{Fe_2O_3} + 0.1\ \mathrm{Al_2O_3} = [\mathrm{CaO}(0.3\ \mathrm{Mg} \cdot 0.6\ \mathrm{FeO} \cdot 0.1\ \mathrm{Al_2O_3}] \cdot 2\ \mathrm{SiO_2} \cdot 0.13\ \mathrm{Fe_2O_3} + (0.6\ \mathrm{MgO}).$$

Concurrently, plagioclase is replaced by scapolite in several instances. The composition ratio of plagioclase to scapolite by which it eplaced may be characterized by the following measurements le 2):

Table 2

le No. ource	Plagioclase Coordinates of Double Axis	% An	Scapolite w	t	w-t	%Me
53 -43	Bz = 65° By = 26° Bx = 83° B = ⊥(001)	40	1.572	1.551	0.021	52
66 -38	Bz = 22° By = 68° Bx = 89° B = ⊥(010)	40	1.575	1.552	0.023	55

urther replacements of the rocks vary in their course, depending lkalinity and chemical potential of oxygen in the reacting solutions. eferred to group II (Figure 3) are replacements of diopside schists ontaining orthoclase, proceding in the following sequence:

$$Di + P \mp Q \rightarrow Px + Pl(Sc) \pm Q \rightarrow Andr + Pl(Sc) \text{ or}$$

$$(Andr + Px) \rightarrow Andr.$$

nder such conditions, the replacement of orthoclase-bearing rocks s with the displacement of orthoclase and scapolite by quartz. eplacements of the type that fit into the IIa group are widely com- They include, for example, some andraditic skarns developed in cts of diopside pegmatites with diopside calciphyres (Di + Cal). following zonation shows clearly in such contacts (thickness of one is up to 4-5 cm):

$$Px' + Cal \rightarrow Cal + Andr \rightarrow Andr + Sc \rightleftarrows Px + Sc \leftarrow Px + Or \leftarrow$$

$$Px + Or + Q.$$

henomena of the direct andradization of orthoclase rocks are here rred to groups III and VI. Under such conditions, the following ence is characteristic, in the replacement of diopside pegmatites:

$$Di + Or \rightarrow Px + Or + Q \rightarrow Andr + Or + Q \rightarrow Andr.$$

dark green clinopyroxene is replaced selectively by andradite, as well as in other rocks. Assuming no changes in the volume, process may be represented by the following reaction:

$$Px + (2.2\ CaO + 1.5\ Fe_2O_3) = 2\ Andr + (0.9\ MgO + 1.5\ FeO).$$

e relative facility of such replacement may be explained by the ancy of silica and alumina contents of the system (the immobile onents) which makes the selective replacement of pyroxene by dite understandable.

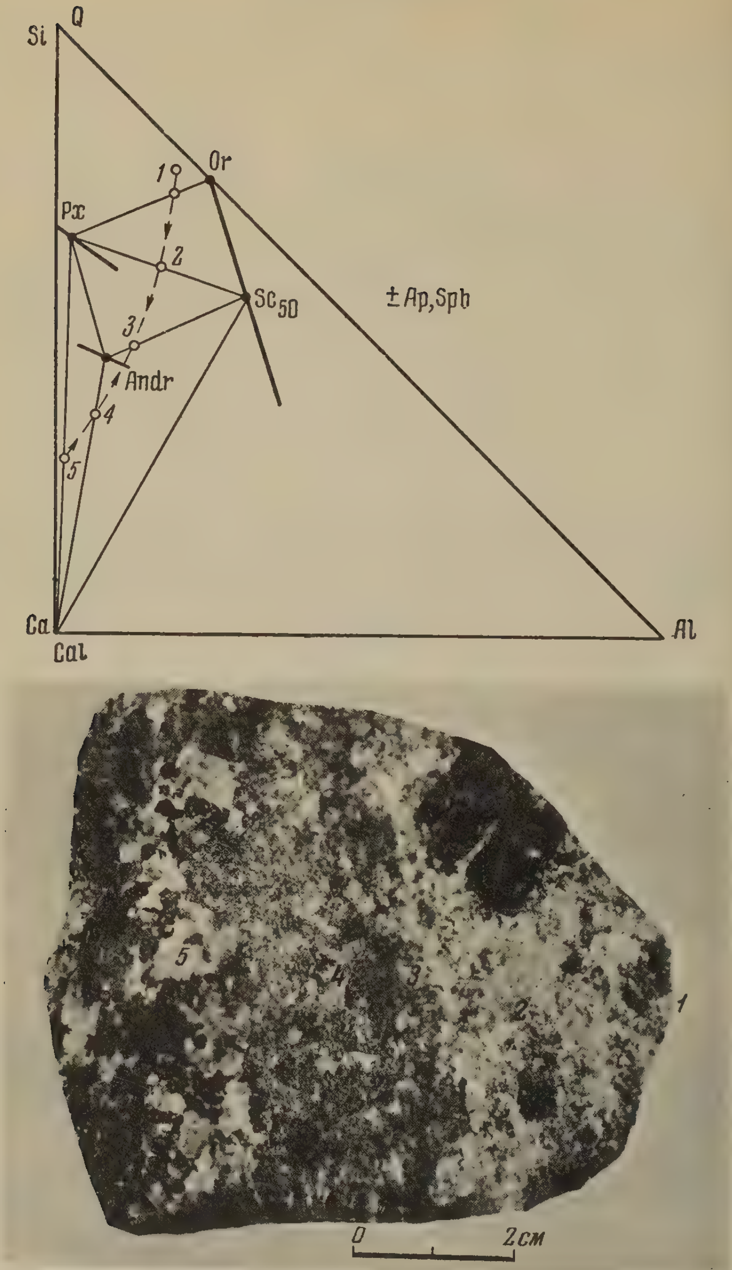

Fig. 4. Parageneses of Limy Skarns. Group IIa. Development of andraditic skarn in the contact of diopside pegmatite with a pyroxene-calcite rock: 1—diopside pegmatite; 2—pyroxene-scapolite rock; 3—skapolite-andradite rock; 4—calcite-andradite rock; 5—pyroxene-calcite rock. Secondary quartz and calcite are present in the rocks. Compositions of the rocks are plotted on the triangular diagram on the basis of quantitative mineral estimations. Sample No. 2214 (Area No. 2, Zapadnaya (western) Quarry, the Emeldzhak deposit.)

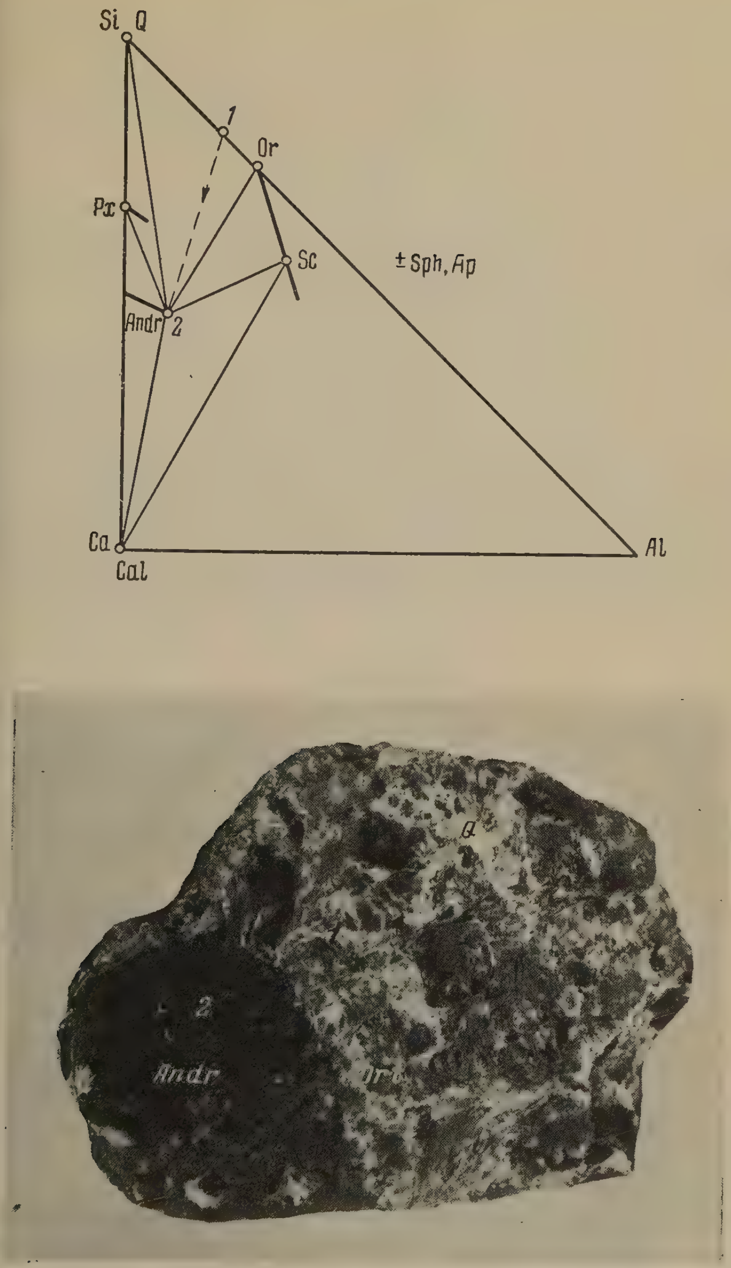

Fig. 5. Parageneses of Limy Skarns, Group VI. Replacement of giant-grained pegmatite, (1) composed of orthoclase-perthite with quartz, by single-mineral andraditic skarn (2). Sample No. 2079 (K-80, Utomitelnyi area). Scale 1:1.

Andradization precedes replacement of rocks by the dark green pyroxene in many cases. We observe pyroxene veins replaced selectively by andradite in the rocks (Or + Q ± Px → Px → Andr).

Finally, we should mention some examples of the direct andradization of pegmatites containing no dark minerals (group VI): Or + Q → Andr.

The single-mineral andratitic skarns are the end-products of the limy metasomatosis of alumino-silicate rocks at the Taezhnoe deposit. Further accessions of calcium may be conducive to the formation of calcitic rocks. Such rare phenomena of the high-temperature carbonization of andraditic skarns were noted also at other analogous sites in Southern Yakutia (Sivaglinsk and Emeldzhak) where the skarns are replaced by pyroxene-calcite and scapolite-calcite rocks.

There are isolated observations on record dealing with the relationship between andradite and metasomatic magnetite. We have examples of the replacement of andradite by magnetite in which andradite is paragenetic with orthoclase (under conditions of relatively high alkalinity). We have examples also of the replacement and of the coating of magnetite by andradite. In these latter cases, andradite is observed in a paragenesis with pyroxene and scapolite, which means that it was formed in an environment with relatively low alkalinity.

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APPLICATION OF THE LEACHING METHOD IN EVALUATING THE SUITABILITY OF SAMPLES FOR AGE DETERMINATIONS BY THE ARGON METHOD

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Abstract

he K and A leaching from potassium-containing minerals by solutions of
m and various acids has been studied. A considerable dissolution of biotite,
ed with strong hot HCl, has been established. The solubility of each biotite
le depends apparently on the state of its preservation. According to the
ned data an interdependence of the solubility of the biotite and the absolute
gical age of the sample has been outlined. Such an interdependence may
to find a criterion for the suitableness of samples for age determination
the argon method.

ccuracy of the determination of the absolute geologic age by any
oactive method depends not only on the accuracy of the decay con-
ts of the radioactive elements themselves but also, to a large ex-
on choice of the test materials. Thus, in the argon method,
ect of the latter factor had resulted in a serious confusion in the
ulations of the radioactive decay constants for potassium. The
ssium minerals used in the determinations of age by the argon
od, feldspars and micas from one and the same site, showed
ous age discrepancies. It had been shown by us, in the Union,
ady in 1953, that there are appreciable discrepancies between the
of feldspars and micas from one and the same place. Discrepan-
of the same kind were reported subsequently also by the American
stigators. These facts made it necessary for us to examine these
rals in reference to their suitability for the argon method.

s a criterion of the suitability of minerals for the helium method,
. Gerling [1] proposed, in 1939, the determination of the heat of
sion. The same criterion was used later [2], in testing suitability
inerals for the argon method. Determinations of the heat of diffu-
for muscovite and biotite had indicated that these micas are suited
st materials for the argon method where the energies of the acti-
n and of the chemical bonds are commensurable magnitudes.
ver, there are marked fluctuations in the heat of diffusion, in all
bility, for micas whose state of preservation is not the same.
fairly exact method of testing suitability of minerals for the age

studies is not adapted for daily use for samples of different kinds,* because of its complexity and its time-consuming operations.

Insofar as the age of minerals depends significantly on the $\frac{mA^{40}}{mK^{40}}$ ratio, the interdependence of K and A becomes a subject of great interest. Phenomena responsible for the losses of these elements fro minerals were studied but incompletely, so far. In order to investigat further this problem, we studied experimentally the effects of weak solutions of soda and of sulfuric acid (0.001N, 0.01N, and 0.1N) on microcline, muscovite, and biotite, at room temperature, for 3, 6, and 9 days. The experiments were accompanied by shaking and showed that there was no leaching of A or of K.

Prolonged action of 0.1N soda and of 0.1N sulfuric acid on biotite, during 2 months, also failed to bring about any appreciable losses of A or K (the observed losses were within the limits of the analytical error for these elements).

We thought it desirable therefore to raise both the temperature and the strength of the reacting solutions. We examined the state of microcline, muscovite, and biotite after their heating in a strong hydrochloric acid solution. The minerals were ground to 1-3 mm particle size and were tested with strong HCl for 1 hour. There were no visib changes in the appearance or in the composition of microcline and muscovite and the amounts of K and A remained, within the limits of analytical error, the same as they were before. A longer treatmen of microcline and muscovite with hot strong HCl, for 5 and for 15 hours, had also failed to cause any solution of A and K.

The hydrochloric acid effect on the state and the chemical composition of biotite was different, however, and accordingly directed our particular attention to that mineral.

As we know from mineralogy [3], biotite is easily soluble in H_2SO_4 but only very weakly soluble in HCl.

Our investigations of biotite contradict the data available in the literature. Treatment of biotite with hot strong HNO_3 or H_2SO_4, for 1 hour, has practically no effect on its chemical composition, whereas a comparable treatment with HCl causes significant changes in the mineral.

Specimens of biotite from different pegmatitic veins of Karelia were crushed to about 1 to 3 mm particle size and were treated with hot concentrated HCl, all other things being the same. After one hour's treatment, the liquid and the solid phases of the system were parted by filtration. The HCl-treated platelets of biotite were easily split, were brittle, and easily mashed between fingers; their color ha changed. The filtrate from the HCl-treated biotite had different colo for different specimens: green, yellow, and the color of strong tea.

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*In the original "for any sample", in the sense of "different kinds of sample VPS

Jntreated samples of biotites were analyzed for A, K, Fe_2O_3, $)_3$, MgO, and SiO_2 and the filtrates obtained by the HCl treatment e analyzed for Fe_2O_3, Al_2O_3, MgO, and SiO_2, in order to ascer- the effects of strong HCl on the mineral. A and K were also rmined in the treated biotites.

Comparison between the results presented in Table 1 shows that A, , Fe_2O_3, Al_2O_3, and MgO are taken out of the mineral in the same portions (i.e. that there is no preferential solubility of any one of e constituents - VPS) by the hot strong HCl treatment, i.e. that we dealing with the solubility of biotites (as such - VPS). This fact is

Table 1*

	Source and Sample Number							
	1. Lokaansaari		2. Panfilova Varaka		3. Lapsieva Guba		4. Kovda	
tuent	Aver. in sample g/g	Per cent solubility	Aver. in sample g/g	Per cent solubility	Aver. in sample g/g	Per cent solubility	Aver. in sample g/g	Per cent solubility
	1.40×10^{-6}	81.3	1.58×10^{-6}	22.9	1.70×10^{-6}	22.9	1.41×10^{-6}	Not detected
)	0.1800	84.2	0.1885	52.2	0.1878	18.6	0.1595	4.5
O_3	0.3330	85.4	0.2925	56.2	0.2790	20.6	not dtd.	not dtd.
$)_3$	0.1340	82.5	0.1629	52.2	0.1375	18.2	not dtd.	not dtd.
)	not dtd.	not dtd.	0.1130	49.5	0.1230	21.0	not dtd.	not dtd.

les provided by A. Ya. Krylov

tained also by the X-ray analysis, for which we are indebted to the rtesy of V. V. Kurbatov. The diffraction patterns of the treated ites are identical with the diffraction patterns of the untreated ites, except for a conspicuous veiling of their lines (due to amorus SiO_2, in all probability - VPS).

Vith the total SiO_2-content of the biotite specimens at 30 to 32%, were able to detect only tenths of one per cent of SiO_2 in the files. This may be explained by the fact that the silica which leached of the biotite passes into its insoluble state and remains on the r, together with the residue of the biotite, after the filtration. orphous silica does not produce any diffraction patterns with the ays and the debaeogram of HCl-treated biotite shows a noticeable for that reason. The fact that A is leached out of biotite in the e proportion as the other elements is an additional convincing ence that it is distributed uniformly throughout the crystal lattice e mineral. As may be seen from Table 1, different biotites have rent solubility in HCl. This phenomenon may be explained by ations in the chemical composition of biotites. However, the kingly different behavior of biotites in HCl, when one biotite re- ns practically undissolved and another one becomes dissolved al- t completely (80%), may be due to differences between their states of preservation. Such differences cannot be determined visually. The biotites we had examined were elastic shining translucent black platelets.

Sample 1 does not look like biotite after the HCl treatment: its platelets are blanched; they mash easily between fingers. Sample 3 shows very little change after the treatment: its platelets are still elastic, shiny, black, with only a faint silvery tinge.

Different responses of the biotites to the HCl treatment show a noticeable correspondence to the age of the specimens.

Comparisons between the determined age of biotites with their solubility (Table 2) suggest a measure of a relationship: the greater the solubility of biotite in HCl--the greater is the difference between the "true" age and the apparent or measured age of the untreated biotite.

On the basis of our preliminary findings, we may state that the choice of the best preserved specimen may be decided by testing stability of many specimens in the presence of HCl, all other things being the same. Thus the 20% solubility of the biotite, under conditions of the test, is an indication of the good state of preservation of the specimen and of its solubility for the determination of the age. The 50% solubility of the biotite is due probably to a poorer preservation of the specimen and the determined age of this biotite is lower than its true age accordingly.

Ascertaining the relationship between age and solubility of the specimen is likely to provide us with a new and simple criterion of

Table 2

Source	mAr^{40}/mK^{40}	Average % of solubility of biotite	Age, 10^6 yrs. (our date)	Age, 10^6 years, according to others
Loilaasaari, Lake Ladoga Area	86.3	80	1600	1800; (after muscovite); (E. I. Starik, N. A. Voroshilov).
Panfilova Varaka, White Sea Area	93	50	1660	1800; after biotite (E.K. Gerling).
Lapsieva Guba, White Sea Area	101.5	20	1780	1800 (Pb^{207}/Pb^{206}); after uraninite (E. I. Starik, G. V. Avdzeiko)
Kovda, Chupinskii District, White Sea Area	100	0	1760	1800; after muscovite (E. K. Gerling).

suitability of biotites for the A method of the determination of their age.

The results here reported are tentative and further studies of the problem are now in progress.

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DETERMINATION OF THE ABSOLUTE GEOLOGIC AGE OF MONAZITES BY THE HELIUM METHOD

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Abstract

Eight samples of carefully selected altered and unaltered monazites have been studied in order to ascertain the possibilities of age determination with the helium method. It has been established that in very carefully selecting the mineral no considerable improvement of the age figures is reached. According to monazites from pegmatites of Karelia the age is too low by 300-500 · 10^6 years. The external macro- and microcharacter of the mineral are no reliable criteria in judging the suitableness of the mineral for determinations. The loss of the chief helium amount probably occurs during the alteration of the mineral under the action of superimposed hydrothermal solutions and not as a consequence of the process of gradual diffusion resulting from the destructive action of radioactive radiations.

Geologic age of monazite may be determined simultaneously by two methods: the helium and the lead. Only a few minerals are analogous to monazite and, so far, there are only a few determinations on record, for khlopinite [10], samarskite, and aeschynite [5], despite their methodologic interest. Indeed, helium—a far more mobile element than lead—should be a very sensitive indicator of various processes by which minerals are altered, particularly recrystallization—a process most highly conducive to losses of helium unaccompanied by any loss of other constituents including those that are alien to the mineral structures, including, specifically, lead.

Comparison of two other methods, the argon and the strontium, is entirely analogous to the former comparison.

The criteria of suitability of a mineral for the helium method, as suggested by E. K. Gerling [3, 4], namely, density of the crystal lattice and the correspondingly high heat of diffusion, were validated for a series of monazites from Central Kazakhstan and Altai. The age measurement for a monazite from Impilyakhti, S. Karelia, gave the figure of 1420 x 10^6 years. However, the same helium method, according to E. K. Gerling, showed only 850 x 10^6 years* as the age of monazites from Cheraya Salma and Chkalov [14].

Such significant lowering of the age, almost by 50%,** was believed to be due to the poor preservation of the mineral and to careless sampling of it.

*Re-calculated from the P. V. Melenter's nomogram.

*In the original: "more than twice". VPS

Because monazite is especially interesting as test material in the determinations of geologic age, we undertook these determinations by the helium method for several monazites from the North Karelian pegmatites, as well as for some others.

All of our pegmatitic monazites, particularly the sulfide-bearing specimens, had undergone alterations by the later hydrothermal solutions. Our observations showed that the monazites from Chernaya Salma are generally coated by a greenish crust which proved to be chiefly sulfide-pyrite, possibly with some pyrrhotite, penetrating the mineral along its small fissures. Sulfides were detected also in the monazites from Severnaya Varaka and Lake Tedino Ozero.

The monazite from Yugas, Kola Peninsula, was also altered severely by late hydrothermal solutions, from which much fluorspar had been deposited. The mineral from a vein at Akchatau, Central Kazakhstan, was altered to a lesser degree.

In regard to the state of preservation, the Akchatau monazite and, next, the Tedino monazite were the best. 0.3 to 0.4 grams, out of 20 to 30 grams of the minerals from Severnaya Varaka and Alakurtti were selected for the analysis. The Alakurtti material was of a poorer quality. Using 250 g of the 0.5 to 0.25 mm fraction of the Chkalov sample, it was possible to select only 1.6 g of the pure (so-called unaltered) mineral. Only 0.6 g of suitable material could be selected, in the case of the Yugas sample, from about the same fraction and the same bulk as in the case of the Chkalov sample. At that, the selected test material was not without defects. All that we could do was to pick out with care and to discard every fragment containing dusty and dot-like inclusions.

In addition to the "unaltered" materials, we had selected also fragments of the altered and completely darkened substance, for the sake of comparison, in several instances.

Uranium and thorium were determined by the emanation method, with the reliability of ± 3 to 5%.

Helium was determined in the Khlopin-Gerling apparatus [2], by fusion of monazite with $KHSO_4$, followed by the purification of the liberated rare gases. The measured volumes of helium were corrected to 0°C and 760 mm pressure.

The emanation coefficient, after Th and Rn, was determined for some of the monazites.

DISCUSSION

Our results are summarized in Table 1. The test materials were placed at our disposal by V. D. Nikitin (Severnaya Varaka, Alakurtti) and by Yu. K. Gumennyi (Yugas). The other samples were collected by one of the authors.

The helium method gives entirely satisfactory results for the age of young (not older than Paleozoic) monazites, as confirmed in the

Table 1. Age of Monazites as Determined by the Helium Method

Source	Character of Mineral	% of Th Duplicates			% of U Duplicates			% of He cm^3/gram	Coefficient of Emanation		Age of mineral x10^6 yrs.
		I	II	Aver.	I	II	Aver.		After Rn	After Th	
Tedino Ozero	Unaltered	4.71	4.90	4.80	0.71	0.63	0.67	3.056 3.049	0.63	0.34	1300
Tedino Ozero	Unaltered	4.75	4.70	4.72	0.65	0.64	0.65	2.304	-	1.9	1050
Severnaya Varaka	Unaltered	5.33	-	5.53	0.58	-	0.58	2.909	-	-	1190
Alakurtti	Unaltered	2.48	2.32	2.40	0.18	0.20	0.19	1.309	-	-	1330
Chkalov	Unaltered	7.32	7.05 6.97	7.11	0.53	0.51 0.55	0.53	2.724	0.13	-	970
Chkalov	Unaltered	7.19	7.05 6.80	7.01	0.49	0.51 0.48	0.49	2.294	1.2	0.3	840
Yugas	Unaltered	3.88	3.60	3.74	0.071	0.077	0.074	1.391	0.5	-	1310
Akchatau	Unaltered	4.90	5.15	5.02	0.111	0.104	0.104	0.444	-	-	284

case of the Akchatau where it coincides with the earlier determinations for monazites from different veins [9]. The same cannot be said about the more ancient—the Archeozoic—monazites. In the case of the Chkalov monazite, for example, despite the most thorough preparation of the test material, the indicated age did not exceed 1000 x 10^6 years—essentially a replication of the earlier figure, 800 x 10^6 years, definitely low. Comparable figures were obtained for the Severnaya Varaka monazites; for the very best preserved monazite (among the ancient ones), from Tedino Ozero, the determined age was 1300 x 10^6 years. The highest figure of 1330 x 10^6 years was obtained, unexpectedly, for one of the worst preserved monazites from Alakurtti. The age of all of these deposits is about the same: 1800 to 1900 million years. Consequently, the negative deviation of the analytical data is about 500 or 600 million years. The determined age difference between the altered and unaltered monazite is not sufficiently great (we expected it to be far greater) to ascribe the losses of helium to the visibly small alterations in the mineral, which are also characteristic of our "unaltered" materials.

The difference between the unaltered and the altered monazite from Yugas, with respect to their helium content, is still smaller and amounts only to 9.5%. The altered variety contains 1.4380 cm^3 He/g.* The visibly significant alteration of the mineral resulted in a relatively small loss of helium.

The X-ray studies of powdered [7] monazites show certain differences in their diffraction patterns. There are similar, but not as markedly, showing differences between the unaltered and the altered monazites in their diffraction patterns. The Akchatau monazite is

*The results for the altered variety are not shown in the Table.

closest, structurally, to synthetic cerium phosphate. The monazites from Chkalov, Severnaya Varaka, and Alakurtti show significantly a lesser perfection in their structures, judging by the smaller numbers of their lines, especially in the small-angle field. Moreover, the monazite from Severnaya Varaka fails, for all practical purposes, to resume its original structure after ignition, whereas the strongly altered Alakurtti monazite resumes its structure to an appreciable extent.

It appears that structural characteristics of different monazites, as shown by the X-ray method, may serve to explain why some of them had lost more helium than some others and why the Alakurtti monazite yields the best age data, despite its visibly poor state of preservation: the less disturbed the structures, the smaller the losses of helium.

Evaluating our results as a whole, we may state that all of the age figures are too low, due to the losses of helium and despite the extreme care in the preparation of the test materials.

Helium should be able to escape from minerals with a greater facility than lead, on account of its pressure inside mineral structures. This is indeed observable, although one might think that the relative quantities of the escaped helium should be many times as great as the quantities of withdrawn lead.

The available data on Karelian monazites [1, 8, 11, 13, 14, 15] indicate that, on occasion, contradictory results may be obtained for the age of monazites from one and the same deposit, some of which may be close to the true age, while others may be too low. The reason for the low results (with or without the isotopic measurements) is the removal of lead from the minerals by subsequently superimposed hydrothermal processes. This was shown to be the case not only in monazites but also in several other minerals [8]. More than one half of the accumulated lead may be lost in such manner, possibly even more, if we consider the fact that removal of lead was begun 500 to 700 million years ago [8]. This process was accompanied undoubtedly by alterations in the mineral itself, and it is entirely probable that the degree of the alteration is directly proportional to the intensity of the withdrawal of lead. It is possible that there was a twice-repeated alteration of the radioactive minerals, by two hydrothermal processes, the early original one and the superimposed later one.

The structural changes, previously discussed, should be interpreted in relation to the second hydrothermal process and do not correspond to the continuous effect of the radioactive emanations.

The available data, although they were obtained for one and the same aliquots of the samples (excepting the Chkalov monazite), show nevertheless that there is no marked difference between amounts of the escaped helium and of the leached-out lead. We may suppose that helium escapes and that lead is leached out from the same parts of the structures which are subjected to a considerable disturbance. Characteristically, the best, i.e. the highest, results for the age, by the helium method, were obtained for the Yugas and the Alakurtti monazites containing the smallest amounts of radiogenic helium, thorium, and especially uranium. Such higher figures for the age of monazites that are the lowest ones in helium may be explained by the losses of relatively smaller quantities of helium during the alterations of the monazites, inasmuch as the helium pressure within the minerals was also low.*

But what is the role of radioactive emanations in the losses of helium from minerals? As we know, there has developed a view among many investigators, especially in recent years, that transitions to the metamict state, together with certain structural disturbances and alterations (accordingly also losses of helium), in minerals like zircon, are related to the destructive effects of radioactive emanations. Also, it is generally believed that sphene too loses a part of its helium by the action of some analogous mechanisms [12]. The authors who adhere to this opinion entirely ignore the possible effects of the subsequent geologic processes. In contrast to such views, one of us believes that it is the subsequent geologic processes and not the radioactive emanations that play the definitive role in the losses of helium by minerals [6].

However, the facts here reported, which have been interpreted as indicative of the effects of the subsequent hydrothermal processes, do not exclude entirely the role of the radioactive emanations in producing partial disarrangement of monazite structures and the resulting losses of helium, which is so extremely difficult to measure as long as the required experimental background is lacking in the research.

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MINOR ELEMENTS IN THE BASEMENT ROCKS OF THE EASTERN PART OF THE RUSSIAN PLATFORM

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Abstract

Using the method of quantitative spectroscopic analysis the determination of Sr, Ba, V, Cr, Mn, Ni and Cu in the rocks of the base of the eastern part of the Russian platform, represented by gneisses and granites, more rarely by gabbros, norites and other magmatic rocks, has been carried out.

The average content of the minor elements in gneisses and granite gneisses of the base is close to their content in sandy-argillaceous rocks. For this reason they may be regarded as sedimentary rocks, having been subjected to metamorphism, with inclusions of magmatic rocks, somewhat more enriched in minor elements of the iron group.

Precambrian metamorphic and magmatic rocks contribute to the structures of the basement of the Russian Platform. The rock constituents of this crystalline basement are granite-gneisses in which some basic rocks may be also encountered: gabbros, diabases, norites, and others.

The following principal chemical constituents of these rocks are indicated by analysis:

SiO_2: 65% average, in granite-gneiss; 50% in diabase; 42 to 48% in amphibolite;

Al_2O_3: 11 to 16%; Fe_2O_3 plus FeO, CaO, and MgO: each 1 to 8% and higher; Na_2O and K_2O: 0.35 to 3.5%; TiO_2: 0.36 to 2.40%; MnO: 0 to 0.20% [1].

We studied the distribution of the minor chemical elements in the crystalline rocks of the basement in the following areas:

Tatar ASSR, the northern part of the Udmurt ASSR, and the Kuibyshev, Ulyanovsk, Penza, and the adjoining areas. 97 samples of the specimens used from the collection of T. E. Baranova, Geologist. Most of these specimens were examined by L. A. Vyrdanyants, petrographer. According to his conclusions, all of the specimens are gneisses of the biotite, amphibolite, granite, sillimanite, and pyroxene types, and also some granites, gabbros, norites, and others. Qualitative and quantitative chemical analyses were done spectrographically [2]. The source was an electric arc, DC, with carbon electrodes and 10a current. A 20 milligram aliquot of the samples was placed in the cavity of the lower electrode, the anode, and was burned completely within 4 minutes. The spectra were recorded by a quartz spectrograph, ISP-22. Artificial mixtures of 14 elements with the SiO_2 base were used as standards. Density of the lines was measured on the logarithmic scale of the MF-2 microphotometer. The standard curves were constructed with the coordinates of $\Delta S' = S - S'$ (background) and log C %.

Sr, Ba, V, Cr, Mn, Ni, Cu, and Ti were determined quantitatively; Zr and Be were determined tentatively; Si, Al, Fe, Ca, Mg, K, Na were measured by the density of the "S'" lines—a procedure that indicates changes in the concentration of these elements, from sample to sample, and offers a basis for a tentative estimation of their concentrations. Accuracy of the quantitative determinations was ± 4 to 11%.

Accuracy of the determinations of copper, on occasions, was ± 20%.

The entire territory is divided into four regions: a) The West of TASSR (Tatarskaya Avtonmnaya Sovetskaya Sotsialisticheskaya Respublika); Ulyanovsk Oblast; b) The central part of the TASSR and the Udmurt ASSR; c) The Southeast of the TASSR; d) The Southwest: Penza, Kuibyshev, and parts of Saratov areas (see table). Judging by densities of lines on the spectrograms, there is very little difference in the concentrations of Si, Al, Na, and K in the majority of the samples, while there are marked differences in the concentrations of Fe, Mg, and Ca. The relatively high densities of the iron lines, "S'" about 0.70 (and, consequently, higher concentrations of iron) are found in samples of rocks from the Southwest. The "S'" about 0.60 is characteristic of the rocks from the western part of the TASSR. There is more Ca in rocks from the West and the Southeast of the TASSR; there is one-half to one-fourth as much Ca in the Southwest and the center of the TASSR. Magnesium is high in rocks from the Southwest and the West of the TASSR; there is less of it in the Southeast and very little in the center of the TASSR.

The results of quantitative analysis for minor elements are shown in the table. Average concentrations are reported in the instance of samples of rocks of the same type collected from several different boreholes in one and the same area.

The Sr average for rocks of the basement is 0.054%; it is somewhat higher for gneisses than for magmatic rocks. The strontium content varies from 0.025% to 0.1% in individual samples. Three samples contain no strontium. Low concentrations of strontium are characteristic for the rocks of the Southwest, where calcium is also low (about 1%) and magnesium is relatively high (3% and higher).

The barium average for rocks of the basement is 0.06%. Gneisses are richer in barium than magmatic rocks. Barium is about the same in granites as in norite-gabbros. There are no differences between the regional barium averages. By comparison with strontium, barium shows abrupt fluctuations in some samples: from trace to 0.2%. The irregular distribution of barium is characteristic also for sedimentary rocks. The Sr:Ba ratio in rocks of the pediment is

Table 1. The Content of Some Elements in Rocks of the Eastern Part of the Russian Platform

Region, Area, Borehole No.	Type of Rock	Depth, Meters	No. of Samples	Per cent							
				Sr	Ba	Ti	V	Cr	Mn	Ni	Cu
1. Northwest											
Yanga-Aul; 2	pyroxene gneiss	1960	1			0.74	0.010	0.27*	0.06	0.14*	0.06*
Urmary; 5, 6	gneiss	1625 to 1818	2	0.09	0.33	0.27	0.009	0.0033	0.011	0.0047	0.003
Urmary; 5	gneiss	1819	1	0.06	0.05	0.60	0.023	0.008	0.04	0.008	0.001
Tatazeleiskaya; 4	granite-gneiss	1775	2	0.08	0.075	0.20	0.005	trace	0.01	--	--
Tonchinskaya; 2-r	gneiss	2100	2	0.09	0.12	0.62	0.0065	0.0035	0.027	0.010	0.010
Yanchikovskaya; 12, 17	--	1630 to 1750	2	0.67	0.095	0.27	0.0055	trace	0.023	0.004	0.0005
Uleminskaya; 6	gneiss	1988	1	0.10	0.05	0.30	0.009	0.002	0.016	0.004	--
Uleminskaya; 4	amphibole	1957	1	0.05	trace	0.90	0.016	0.013	0.30	0.018	0.003
Karly; 1	gneiss	1778	1	0.07	0.05	0.45	0.020	0.013	0.07	0.010	--
Karly; 2	granite	1705	1	0.07	0.05	0.35	0.020	0.018	0.02	0.008	trace
Regional Average			14/7	0.0624	0.058	0.47	0.0107	0.0053	0.05	0.006	0.002
2. Central											
Varzi-Yatchi; 7	porphyrite	1859	1*	--	--	present	0.040	0.026	0.25	0.015	0.12
Yelabuga (five holes)**	granite-gneiss	1580 to 1680	9	0.064	0.09	0.37	0.0056	0.001	0.05	0.0046	0.0005
Bondyuzhskaya; 42	gabbro-gneiss	1625	1	0.026	0.05	1.0	0.007	--	0.17	0.004	0.003
Novo-Mussatova; 12, 27	gneiss	1730	3	0.08	0.11	0.20	0.003	0.005	0.07	0.006	0.004
Kermenskay; 12	gneiss	1625	1	0.08	0.8*	0.75	0.008	--	0.05	0.005	trace
Chistopol; 6	gneiss	1700	3	0.067	0.05	0.14	0.002	trace	0.014	--	trace
Regional Average			18/6	0.053	0.06	0.40	0.005	0.0012	0.06	0.004	0.0015

3. Southeast											
Popovka (5 holes)	gneiss	1665 to 1725	5	0.08	0.086	0.22	0.0026	0.0035	0.058	0.0042	0.0003
Suleevo (7 holes)*	gneiss	1730 to 1829	9	0.08	0.12	0.37	0.0043	0.007	0.050	0.007	0.0032
Suleevo (572 holes)	quartz magnetite	1663	1						0.10	0.0035	0.016
Suleevo (14 holes)*	gabbro	1757	1	0.09	0.16	0.70	0.010	0.0013	0.08	0.005	trace
Suleevo (82 holes)**	gabbro	1778	1	0.025	trace	0.70	0.030	0.013	0.30	0.016	0.0004
Suleevo (575 holes)**	norite	1820	1	0.04	trace	0.55	0.010	0.016	0.16	0.013	0.007
Suleevo (653 holes)**	norite	1858	1	0.06	0.08	0.45	0.006	0.005	0.016	0.005	0.0013
Sarmanovskyaya; 61	amphibolite	1714	1	0.45	trace	0.60	0.010	0.013	0.12	0.020	0.010
Muslyumovskaya; 67	gneiss	1760	1	0.09	0.07	0.30	0.004	0.011	0.02	0.0045	trace
Aktash; 68, 100	granite	1840	2	0.042	0.01	0.53	0.011	0.007	0.045	0.009	0.015
Aktash; 106, 20	gabbro	1700 to 1740	3	0.053	0.087	0.97	0.018	0.009	0.055	0.008	0.0027
Aktash (7 holes)**	gneiss	1700 to 1800	13	0.047	0.07	0.44	0.014	0.006	0.055	0.0063	0.005
Novo-Elkhovskaya; 49, 52, 58	gneiss	1800	4	0.08	0.16	0.47	0.0052	0.009	0.021	0.007	0.002
Novo-Ibraikinskaya; 43, 64	gneiss	1816	2	0.05	0.05	0.65	0.011	trace	0.044	0.0045	0.0023
Cheremshan; 20	gneiss	1732	2	0.04	0.055	0.30	0.003	trace	0.040	0.0035	0.002
Aznakaevo; 27		1725	2	0.077	0.05	0.16	0.0025	0.0008	0.008	0.0043	trace
Argunovskaya; 19	gabbro	1745	2	0.05	0.01	0.50	0.0075	0.0027	0.07	0.008	0.010
Regional Average			51/10	0.063	0.064	0.40	0.0067	0.0043	0.052	0.0048	0.0025
4. Southwest											
Samarskaya Luka (Zhigulevsk; 3)	biotite gneiss	1869	1	0.05	0.06	Ca 1.0	0.10		0.024	0.005	
Komarovskaya; 4, 9	gneiss	2078	5	0.04	0.048	0.30	0.013	0.007	0.038	0.007	0.006
Novo-Tomashevskaya; 1	granite-gneiss	1680	1	0.05	0.05	trace			0.006		
Rep'evka; 1	granite-gneiss	2045	1	0.028	0.005	0.08	0.009	trace	0.015	0.004	0.0007
Varvarovka; 1	gneiss	1790	7	0.04	0.06	0.40	0.014	0.013	0.127	0.009	0.0020
Verkhozinskaya; 3	gneiss	2030	1	0.03	0.07	0.90	0.023	0.016	0.13	0.009	0.0016
Kikinskaya; 12	weathered crust	1900	1	0.03	0.08	1.50	0.028	0.04	0.020	0.024	0.0012
Regional Average			17/7	0.038	0.060	0.53	0.014	0.011	0.05	0.0083	0.002
Average for Pediment Rocks			99	0.054	0.060	0.45	0.0093	0.0055	0.052	0.003	0.002
Average for gneiss			84	0.060	0.067	0.44	0.0085	0.005	0.05	0.0056	0.0015
Average for granite			4	0.054	0.040	0.30	0.011	0.008	0.023	0.006	0.0026
Average for gabbro-norite			8	0.051	0.040	0.68	0.0134	0.0096	0.12	0.012	0.0042

*Not used in calculations of the average.

**"po," followed by a number may mean either a composite sample of several holes (in which case the number is the number of boreholes in the composite) or "according to hole such-and-such" (which is not in harmony with the heading of this column). Neither the text nor the table help to understand this departure. VPS

0.9; it is 0.8 in the lithosphere; 1.2 - in igneous rocks; 0.8 - in sediments (clays) [3, 4]. Rocks of the basement, in the eastern part of the Russian Platform, are very similar therefore to sediments, in regard to their Sr:Ba ratio.

There are large variations in the relative abundance of the minor elements of the Iron Group in the rocks of the basement. The average content of titanium in these rocks is 0.45%, i.e., about the same as in igneous rocks and clays. Gabbro-norites contain more than twice as much titanium as is found in granites; there is just as much titanium in gneisses as there is in clays; titanium is higher, 1.50%, in the weathered crust (Borehole 12, Kikino). A regional lowering of the titanium concentrations is observed in the central and in the southeastern parts of the TASSR. Vanadium is lower in the rocks of the basement (0.0043%) than in igneous rocks (0.015%) or in clays (0.012%) [3]. Vanadium is lower in gneisses than in magmatic rocks. Rocks of the Southwest of the territory here discussed are higher in vanadium than rocks of the other regions. Vanadium is particularly low in rocks of the center of the TASSR. The distribution of vanadium in gneisses resembles its distribution in aleurolitic (siltstone - VPS)—clayey sedimentary rocks. The distribution of chromium shows the same relationships as the distribution of vanadium. Rocks of the basement are lower in chromium than igneous rocks [3], although their average chromium coincides with the average chromium content of average igneous rocks [4]. Chromium is especially low in rocks of the center of the TASSR, but is very high in the pyroxene gneiss from Yanga-Aul and in the porphyrite from Varzi-Yatchi.

The average manganese content in rocks of the basement is 0.052%. There is significantly more manganese in gabbro-norites than in granites or gneisses. The manganese content varies in different samples from 0.006 to 0.3%. The average nickel constitutes 0.006%, in the rocks of the basement, i.e., is somewhat below the igneous rocks and the clay average of 0.008%. Nickel is twice as high in gabbro-norites as it is in gneisses or granites. Rocks of the Southwest are somewhat higher in nickel than rocks of the other regions. Copper is distributed more uniformly in the basement, but its average content is low: 0.0020%. Zirconium is present in all samples here studied and its content may be correlated with that of titanium. The Zr average is about 0.017%. Beryllium was found in 25 samples, in the 0.0001 to 0.0005% range; there is no definite tendency for beryllium to be associated with any particular type of rock. The distribution averages for chemical elements in the metamorphic rocks (gneisses) of the basement, in the eastern part of the Russian Platform, show that these rocks were formed from sedimentary aleurolitic—clayey materials. The intrusion of magmatic rocks into the metamorphics had imposed a certain background over the original relative abundance pattern, increasing thereby in places, concentrations of the elements that are characteristic of basic rocks, or where the intruding magmatic rocks were acidic, lowering the concentrations of these elements. The range of variation of these elements in the rocks of the basement resembles their range in sedimentary rocks (Mn, Cr, V, Ni, Ba). Ultrabasic rocks exerted no observable influence on the crystalline rocks of the Pediment; their presence is recorded only locally (at Yanga-Aul, possibly at Varzi-Yatchi).

There are regional differences in the distribution of chemical elements within the territory under consideration. Specifically, rocks of the Southwest (Penza and adjoining areas) are enriched with respect to the iron group (Fe, V, Cr, Ni) which is probably due to the petrography of the Precambrian relatively clayey sedimentary rocks subjected to the metamorphism. Rocks in the central part of the TASSR, on the contrary, had a sandy aleurolitic composition. It follows from our results that studies of the minor elements in the rocks of the Pediment may provide us with additional information on environments in which these rocks were formed and may clarify certain relationships that would escape our attention if our studies were confined only to the common elements.

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CHRONICLE

The International Conference on Application of Radioactive Isotopes in Research

(Paris, September 9 - 20, 1957)

The International Conference on Application of Radioactive Isotopes in Research was held in Paris, 9th to 20th September, 1957. This Conference was organized by UNESCO (The United Nations Educational, Scientific, and Cultural Organization) in accordance with the resolution adopted at the General Conference of UNESCO in New Dehli, in 1956.

More than 1,000 delegates from 61 countries and several organizations participated in the Conference.

At the solemn opening of the Conference on the 9th of September at the Great Amphitheater of the Sorbonne, the well-known British physicist, J. D. Cockcroft, President of the Conference, remarked that rare are examples in the history of science of some particular method of research serving as the topic of a special conference embracing representatives of both science and technology.

The 225 reports presented were, with some isolated exceptions, submitted and published earlier; copies were distributed among all Conference participants. This measure facilitated the work, inasmuch as it was conducive to active audience participation in discussion of the reports.

The reports were divided into 2 sections: physical (including chemistry and technology) and biological, both of which were functioning in the superbly equipped new building of the Faculty of Medicine.

The sessions were organized according to topics.

The Physical Section had 20 sessions with reports and discussions on the following topics: production of radioactive isotopes; dosimetry; production and application of high-power materials; physics of metals; metallurgy; industrial applications; solid state physics; organic chemistry; chemical kinetics; analytical chemistry; physical chemistry; geophysics; the problem of even numbers of nucleons in physics.

The Biological Section dealt with the following topics: pharmacology; metabolism in animal and plant organisms; clinical physiology; photosynthesis; biosynthesis; productivity of water reservoirs. Two joint sessions were given to methods and techniques of research.

The Conference showed that the use of radioactive isotopes is now firmly established in research, both in science and technology, and that definite major results have already been obtained in this new field.

Reports by Soviet authors were in the foreground in certain problems.

A general impression gained from the Conference was that application of radioactive isotopes is a highly developed research technique, especially in the field of measurements of low-energy radioactive emanations.

A large number of the reports, including Soviet contributions, was on subjects of various chemical reactions and processes taking place in solid bodies studied by means of "tagged" atoms.

Although problems of geochemical character were not a part of the basic program, several papers of immediate interest for geochemists were presented at two of the geophysical sessions.

The report by W. F. Libby, an American scientist, on applications of tritium measurements in research on dynamics of waters of the earth's surface aroused a great deal of interest.

The report of T. P. Kohman, an American scientist, dealt with an attempt at detection of radioactive isotopes in meteorites. Such isotopes, the product of bombardment by cosmic particles, had not been previously found in meteorites.

E. Picciotto, a Belgian scientist, discussed his work using nuclear photographic plates in his studies of certain problems of geophysics and geochemistry, chiefly in the micro-distribution of natural alpha-radiating radioactive isotopes.

Three of the reports at the Conference were devoted to the methods of absolute geochronology based on radioactive decay. W. Herr and E. Mertz, German scientists (West Germany), discussed, in principle, the possibility of determining the absolute geologic age by decay of Lu^{176}. E. K. Gerling, a Soviet scientist, discussed the theoretical premises of the potassium-argon method of age determinations. The report by V. I. Baranov and L. A. Kuzmina dealt with the ionium method of sedimentation rates in oceans.

Two papers by Soviet scientists were concerned with isotopic composition of meteoritic materials. Existence of the previously unknown isotope K^{38} was proved by E. K. Gerling in his report.

A. P. Vinogradov, in his paper, made use of the comparison between the isotopic composition of the earth's crust and of meteoric materials as an approach to the problem of origin of meteorites. There was considerable interest in the problems of meteorites, particularly the ones that were posed by Vinogradov, and accordingly a brief symposium was conducted entirely on the subject of meteorites.

Several lectures were delivered by scientific leaders from different countries during the Conference, and some scientific popular films were shown. There was also an exhibit of apparatus used in research on radioactive isotopes.

The Conference, of excellent organization, concluded with a high degree of success. Its participants made firm their international scientific contacts and established some new ones. They benefited undoubtedly by their acquaintance with the organization of studies at several French institutes and establishments. We should note here the high cultural level of research at newly developed organizations and institutes, dedicated to atomic energy problems, such as the Saclay Atomic Center* near Paris.

V. I. Baranov

Symposium on Geochemistry of Rare Elements in Relation to Problems of Petrogenesis

(Moscow, December 20 - 24, 1957)

The symposium on the problems on geochemistry of rare elements in igneous rocks in relation to the problem of petrogenesis was held on December 20-24, 1957, at the V. I. Vernadskii Memorial Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR. Research in geochemistry of rare elements in igneous rocks has acquired a wide scope in recent years, so that not only geochemists but also petrographers are applying themselves to the problem. Research and inquiry into even the most general relationships in the geochemical history of an element have shown that data on geochemistry of rare elements of magmas may be employed theoretically as additional evidence in understanding differentiation of magmatic complexes and in the deciphering of the magmatic history of individual regions. The problem before the participants of the Symposium was to examine geochemical and crystallo-chemical relationships in the behavior of rare elements in igneous rocks and to evaluate the suitability of these relationships for solutions of petrogenetic problems.

The Symposium has created considerable interest among the geologic community of the Soviet Union, as well as abroad. The work of the Symposium was shared by geochemists and petrographers of Moscow, Leningrad, Kiev, Tbilisi, Irkutsk, Novosibirsk, Kirovsk, and other cities of the Union. Moreover, the work of the Symposium was shared by Professors L. H. Ahrens (South Africa), D. Dzhyushka (Romania), E. Ingerson (USA), E. Szádeczky-Kardoss (Hungary), J. Kokta (Czechoslovakia), M. Savul (Romania), and K. Smulikowski (Poland). The first two days of the Symposium were given to presentation and discussion of reports on the abundance relationships of specific rare elements in igneous rocks: Scandium and vanadium (V. V. Shcherbina); rare earths, zirconium, and hafnium (A. I. Tugarinov and E. E. Vainshtein); niobium and tantalum (V. I. Gerasimovskii and E. B. Znamenskii); beryllium (A. A. Beus); rubidium and cesium (L. H. Ahrens); lead, zinc, and molybdenum (L. V. Tauson and Z. V. Studenikova). Also, Prof. E. Ingerson presented a special communication on the geochemistry of rare earths in pegmatites. Each report was followed by a discussion.

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*Gif-sur-Yvette, Centre d'Études Nucléaires de Saclay.

The third day of the Symposium was given to the reports by V. S. Koptev-Dvornikov, M. G. Rub, E. V. Negrey and L. V. Dmitriev, E. Szádeczky-Kardoss, and A. P. Vinogradov dealing with the general aspects of the problem under discussion. The report by V. S. Koptev-Dvornikov and co-workers, devoted to the relationships in the formation of intrusive bodies, led to a lively discussion. Prof. E. Szádeczky-Kardoss devoted his introduction to 1) the role of volatile substances, primarily water, in the formation of intrusive bodies, and 2) to his theory of transvaporization. Participants of the Symposium listened with great interest to A. P. Vinogradov's report dealing with the isotopic proportions in magmatic rocks and with general problems involved in the formation of the earth's crust. Particularly interesting were A. P. Vinogradov's ideas about the zonal mechanism responsible for the fusion of crustal material. In addition to the reports here mentioned, the theses of the paper, "Crystal-Chemistry of Fundamental Petrologic Process," by N. V. Belov—who was unable to attend—were read at the Symposium. The last day of the Symposium was dedicated to a general discussion of the problem as a whole with the participation of 25 people.

There was a particularly animated discussion of problems of uniform and irregular distribution of rare elements in igneous rocks, of the range of variation of their content in the rock, and the required degree of precision in analytical studies.

Some interesting empirical data were cited on several occasions suggesting possibilities of the use of geochemistry of rare elements in unraveling certain specific problems in petrogenesis.

At the time of the general discussion, there were many expressions of the desirability of a closer contact between geochemists and petrographers. Many of the participants stated the desirability of periodic symposia, like the present one, as well as of a continued examination of the current problem at the 21st Session of the Geologic Congress in 1960 at Copenhagen.

In his concluding word, A. P. Vinogradov commented on the success of the Symposium, while noting major aspects of problems highlighted during the discussion.

It should be pointed out that there was a general interest in the data summaries from the literature on geochemistry of individual elements in igneous rocks and minerals compiled by the V. I. Vernadskii Memorial Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR.

The Symposium showed that research in geochemistry of rare elements in igneous rocks is now one of the fundamental lines of work of geochemists and that it has received a broad development in the Soviet Union in recent years. Aside from its independent scientific and practical value, such studies constitute the basis of further investigations of geochemical history of elements in post-magmatic processes and, primarily, in ore formation.

L. V. Tauson

Geokhimiya began publication in 1956 under the able editorship of A. P. Vinogradov. It is the Soviet counterpart of *Geochimica et Cosmochimica Acta,* having practically identical fields of interest and coverage and publishing approximately the same number of pages per year. With the great increase in geochemical research in the U.S.S.R., there have come into being a variety of highly specialized journals in geochemistry and related fields. It is probably better to begin translating this more general journal first and follow with some of the more specialized ones if interest appears to justify this course of action and if the financial arrangements can be made. It is hoped that there will be sufficient interest in this journal to justify translation and publication (as complete volumes) of the issues for 1957 and 1956. If individuals and organizations who would purchase such translations will write to one of the Editors, the work will be undertaken when enough expressions of interest have been received to justify the expense involved. Prices presumably would be approximately the same as for the 1958 issues.

The National Science Foundation has been most cooperative in this venture. They not only indicated willingness to back it financially but also helped in calculating probable costs and possible subscription income during the first year. It is on these figures, and those for advertising and administration, that the grant is based. It is a pleasure to acknowledge here the advice, assistance and support of the National Science Foundation.

Earl Ingerson
Translation Editor

In matters of subscription for Geokhimiya refer to: Moskva K-104, Pushkinsakaya, 23, Akademkniga. Chief Editor: A. P. Vinogradov. Editorial Council: V. I. Baranov, K. A. Vlasov, V. I. Gerasimovskii, D. S. Korzhinskii, A. A. Saukov, N. I. Khitrov (Responsible Secretary), V. V. Scherbina (Deputy Chief Editor).

Geochemical News is an informal bi-monthly newsletter published by the Geochemical Society and sent without charge to all of its members. It contains news of the activities of the Society, such as summaries of Council Meetings, reports of committees and plans for the future. It also includes announcements of forthcoming meetings and symposia of interest to geochemists, personalia, announcements or short reviews of books of geochemical interest, information on translations and translation services, letters and short notes by members, etc.

During 1959 the *Geochemical News* will contain a series of articles on research in geochemistry in laboratories in the United States, not only those associated with universities but industrial laboratories as well.

Subscriptions are available to institutions at $2.00 per year. Orders should be sent to the Treasurer:

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Geochimica et Cosmochimica Acta is the official journal of the Geochemical Society. It is an international journal interested in the broad aspects of geochemistry, both geographically and subject-wise; articles have been received from contributors from all of the (inhabited) continents.

New chemical data and interpretations involving chemical principles are emphasized. For example, papers in chemical mineralogy, petrology, oceanography and volcanology are acceptable, as are those in the chemistry of meteorites, whereas it would be suggested that those in descriptive mineralogy and volcanology, petrography, physical and biological oceanography and physical meteorites, be sent to other journals specializing in these subjects.

Thus, the subject coverage is closely similar to that of *Geokhimiya.* Also, the number of pages published per year is of the same order of magnitude. Subscription prices are as follows:

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